REGIONAL ECOLOGY OF THE ST. ELIAS MOUNTAIN PARKS
A Synthesis with Management Implications

by

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ABSTRACT

The St. Elias region of North America occupies portions of British Columbia, Alaska, and the Yukon Territory and comprises a network of public lands and protected areas managed by a variety of agencies. This thesis characterizes and analyzes the broad-scale, or regional, ecology of these lands and provides an assessment of the implications this has for ecosystem-based management - particularly as it relates to intergovernmental cooperation. A multi-stage, map-based, multidisciplinary process is used to synthesize information on the region's physical, biological, and institutional environments. The fields of conservation biology and landscape ecology provide theoretical foundations for analysis.

The ecological synthesis and analysis illustrates numerous ecosystem components that are shared throughout the entire St. Elias region as well as physical and biological features and processes that serve as linkages between the region's parks and protected areas. Yet the synthesis and analysis also indicate that there are equally as many differences between the parks and protected areas, and that these areas are just as closely linked with surrounding unprotected areas. In combination, these results indicate that the greater St. Elias region actually represents the point at which several different regional-scale ecosystems converge, rather than a single, coherent ecological unit.

These results suggest that an ecological foundation for improved cooperation between management agencies does exist, but not in the form of an integrated, region-wide initiative as originally anticipated. Instead, the regional ecology of the St. Elias

Mountain Parks and surroundings seems to advocate a more process-oriented approach to management wherein the exact boundaries of management are of secondary importance to the development of a coordinated set of principles, goals, and objectives to guide planning and management. Nevertheless, defining spatially-oriented frameworks for integrated intergovernmental cooperation is seen as a key component of facilitating ecosystem-based management and five such areas are identified and recommended. The use of adaptive management and cumulative effects assessment are seen as valuable tools for use in ensuring the maintenance of ecological integrity and wilderness character of these areas and the region as a whole.

"Conservation efforts are like the landscapes they seek to protect. Just as a weakened, isolated ecosystem is strengthened by connections to other land areas, separate conservation efforts can gain from the support provided by a larger network."

Dr. Gary Tabor, 1996

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LIST OF ABBREVIATIONS

ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
BC MELP	British Columbia Ministry of Environment, Lands, and Parks
BRD	Biological Research Division
Chugach NF/CNF	Chugach National Forest
CWS	Canadian Wildlife Service
DIANA	Canadian Department of Indian and Northern Affairs
ESRI	Environmental Systems Research Institute
FWS	United States Fish and Wildlife Service
GLBA	Glacier Bay National Park and Preserve
KWS	Kluane Wildlife Sanctuary
KNP	Kluane National Park
NOAA	National Oceanic and Atmospheric Administration
NP	National Park
NPP	National Park and Preserve
NPR	National Park Reserve
NPS	United States National Park Service
NR CAN	Natural Resources Canada
NTS	National Topographic System
PP	Provincial Park
RRC	Renewable Resources Council
TAT/Tat-Alsek	Tatshenshini-Alsek Wilderness Provincial Park
Tetlin NWR	Tetlin National Wildlife Refuge
Tongass NF/TNF	Tongass National Forest
UN	United Nations
USDA	United States Department of Agriculture
USDI	United States Department of the Interior
USDS	Department of State
USFS	United States Forest Service
USGS	United States Geological Survey
WLU	Wilfrid Laurier University
WRST	Wrangell-St. Elias National Park and Preserve
YDRR	Yukon Department of Renewable Resources
YTG	Yukon Territorial Government

CHAPTER ONE
INTRODUCTION

1.1 INTRODUCTION

This thesis presents research undertaken on the transborder parks and protected areas of the St. Elias region of North America. The goal of the study is to identify and characterize the broad-scale ecological features and patterns of the region and, in turn, provide some assessment of the implications these have for management of the region - particularly as it relates to cooperation between the parks and protected areas and adjacent unprotected lands. This chapter introduces the reader to the concept of regional-scale ecology and to the notion of managing parks and protected areas within the context of their regional ecological setting (Section 1.2) and provides a general introduction to the St. Elias Region (1.3). It demonstrates the need for this study (1.4) and presents its goal and objectives (1.5) as well as expected results (1.6). The final section (1.7) presents a brief outline of how the thesis is structured.

1.2 REGIONAL ECOLOGY AND PROTECTED AREA MANAGEMENT

The United States and Canada have played significant roles in developing the modern concept of parks and protected areas. Yellowstone National Park, the world's first such protected area, was established in 1872 and Banff National Park, the third, was established in 1885 (Dickinson, 1995). Today, the World Conservation Union (IUCN) defines a protected area as "an area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (IUCN, 1994). Based on this definition, parks and protected areas now total more than 1.8 million km^2 in the United States and Canada (WCMC, 1997), and are widely recognized as an integral component of conservation strategies at all scales (e.g. WCED, 1987; Hummel, 1989; Riley and Mohr, 1994). Yet, while protected areas are necessary, it is often a practical impossibility to make them large enough, or numerous enough, to adequately protect biodiversity over the long term (Noss, 1996a). Thus, there is a growing consensus that parks and protected areas must be viewed and managed within the context of the larger ecological systems they occupy (Wright, 1996a). This concept is strongly supported by a growing literature in the interdisciplinary fields of conservation biology and landscape ecology.

Conservation biology is an emerging science that has developed in response to the world-wide loss of biological diversity (Fielder and Jain, 1993). It applies knowledge and principles from academic disciplines such as population biology, ecology, and genetics to fields such as fisheries and wildlife management, forestry, and protected area planning and management and aims to develop scientific principles of conservation and bridge the gap between ecological science and resources management (Primack, 1993; Western, 1989; Soule, 1985). Landscape ecology is an interdisciplinary science that has developed on the interface between geography and ecology (Zonneveld, 1995; Naveh and Lieberman, 1994). Despite recognized differences between European and North American approaches (e.g. Zonneveld and Foreman, 1990), the overall emphasis of landscape ecology can be described as a holistic interpretation and analysis of heterogeneity - spatial and temporal - at the landscape scale (Bunce and Jongman, 1993).

Angelstam (1992) describes conservation biology and landscape ecology as "two sides of a coin" (pg. 13). While both study biodiversity and express concern over the loss of heterogeneity in natural systems, their focal scales are markedly different. Conservation biology is oriented towards the study of features and processes occurring at the genetic and species level while landscape ecology aims to understand ecological features and processes occurring at ecosystem and landscape scales. Regardless of this difference, both fields have significant implications at broad spatial scales. Perhaps most relevant to this study, research in these fields has established the fact that extensive areas are necessary to sustain biodiversity and key ecological processes. The study of such areas and the broad-scale ecological patterns and processes that occur within them is increasingly referred to as *regional ecology*; a field described by Foreman (1995) as "a research frontier of major significance in planning, conservation, policy, and sustainability" (pg. 513).

Despite its practical implications, regional ecology remains a largely conceptual field. James Brown of the University of New Mexico, a recognized leader in the area of regional ecological thinking, has suggested that this is primarily a result of a predilection amongst ecologists towards a reductionist, hypothesis-testing experimental approach which is poorly suited to application at broad scales. In response, he identified six key challenges in the application of ecology to investigations at regional and global scales: (i) develop non-experimental approaches to broaden the scale of ecological research; (ii) develop new statistical tools for analysis; (iii) establish links with other disciplines; (iv) emphasize synthesis, integration, and modelling; (v) standardize and control the quality of data; and, (vi) incorporate humans and their activities (Brown, 1994). It is the first and fourth of these six challenges in particular that this thesis addresses.

The influence of regional ecology and related broad-scale thinking is apparent in the application of conservation biology and landscape ecology to regional conservation planning, particularly in proposals to link existing protected areas through networks of corridors to maintain or restore linkages between these areas at regional and continental scales (e.g. Noss, 1987; Harvey, 1998); to integrate management of protected areas and nearby multiple use lands as broad "conservation networks" (Salwasser *et al.*, 1987); and to manage protected areas as centerpieces in broader, regional conservation strategies (e.g. Grumbine, 1990). Although each of these - and particularly the last - have their origins in the Biosphere Reserve model (Batisse, 1982), they are increasingly being placed under the umbrella of ecosystem management (e.g. Agee and Johnson, 1988) or ecosystem-based management (e.g. Slocombe, 1993) because they apply ecological theory to land use planning and management. While definitions of ecosystem management vary greatly, most definitions recognize the complexity and interconnective nature of ecosystems and are rooted in the notion of enlarging the focus of environmental management to incorporate entire ecosystems, rather than individual components.

In frontier - or border - regions, where international boundaries often transect ecosystems, transborder protected areas can act as a vehicle for a regional ecosystem-based management approach. By combining to preserve large continuous areas of land, transborder reserves reduce the fragmentation associated with arbitrarily drawn boundaries and may ensure protection of complete watersheds, wildlife populations, ecosystems, or key ecological features that would not necessarily be protected or represented by a single component of the reserve (Danby, 1997; Breymeyer and Noble, 1996). Furthermore, these areas promote thinking on a regional scale by acting as a bridge between two or more nations and management jurisdictions.

An essential and integral component of any ecosystem-based management approach is the need for interjurisdictional cooperation and coordination (Cortner, 1994). Implicit here is the concept that the degree to which jurisdictions interrelate with each other at an ecological level dictates the extent to which cooperation and coordination occurs. However, despite being immediately adjacent to each other, the individual components of transborder protected areas are most often managed independently with limited cooperation and coordination of activities (Hamilton *et al.*, 1996). If a regional approach to conservation is to be implemented in border regions, cooperation between management agencies is required. A logical component in promoting the value of such cooperation is to identify shared resources and ecological linkages between individual components of the larger protected area. Furthermore, a regional perspective can be fostered by illustrating the connections between the parks and their surrounding unprotected landscape. As discussed in the following section, the St. Elias Region provides an interesting and instructive example of the need for such an exercise.

1.3 THE ST. ELIAS REGION

1.3.1 General Description

The St. Elias region of North America occupies portions of British Columbia, Alaska, and the Yukon Territory (Figure 1.1). The geologically young Wrangell and Saint Elias mountain ranges form its backbone, with its perimeter marked roughly by the Gulf of Alaska, the Shakwak Trench in the Yukon, and the Copper River valley in Alaska (Wright, 1981). The area exceeds 100,000 km^2 and ranges in elevation from sea level to 5,959 m (Schmidt, 1992). It is the source of several large watersheds including the Tatshenshini-Alsek, Chitina-Copper, and Tanana, and contains the largest non-polar icefield in the world (Theberge, 1980). In the words of Gerald Wright (1981), the region constitutes "a distinct landscape unit... sharing a common geologic, ecologic, and cultural heritage" (pg. 6).

Considering its northerly latitude, the region is rich in biodiversity - due largely to its geographic location and variation in elevation. Northern coniferous or boreal forests characterized by white and/or black spruce (*Picea glauca*, *P. mariana*) predominate the interior lowlands, while in coastal areas, forests of Sitka spruce (*Picea sitchensis*), and western and mountain hemlock (*Tsuga heterophylla, T. mertensiana*) are predominant. Forests give way to subalpine zones of tall shrubs at higher elevations which, in turn, give way to alpine meadows, tundra, and permanent snow and ice at the highest elevations. Fauna is also diverse, and the region is well known for globally significant populations of large terrestrial mammals, particularly grizzly bear (*Ursus arctos*) and Dall sheep (*Ovis dalli*).

While the St. Elias region has a long settlement history, beginning with indigenous peoples thousands of years ago, it remains sparsely populated. Major economic activities within the region include mining and tourism, as well as forestry and fishing along the

Figure 1.1: The Greater St. Elias Region of North America

coastal areas. Hunting and guiding occur where permitted and subsistence hunting by aboriginal peoples and other local residents continues today (Slocombe, 1992).

1.3.2 Wilderness and Protected Areas

The St. Elias region is comprised of a network of public lands and protected areas managed by a variety of federal, state, provincial, and territorial agencies. It is, in essence, one large protected area with Wrangell-St. Elias National Park and Preserve and Glacier Bay National Park and Preserve in Alaska, Kluane National Park and Reserve in the Yukon Territory, and the Tatshenshini-Alsek Wilderness Provincial Park in British Columbia forming its core. In total these four parks protect more than 98,000 km^2 and combine to form the largest UNESCO World Heritage Site. In comparison to other large mountainous regions in North America, such as the southern Canadian Rockies or the Greater Yellowstone Ecosystem, the existing threats to these protected areas - both internal and external - are minimal. As a result, much of the St. Elias Region exists as an intact, relatively undisturbed, mountain wilderness.

Despite - and in some cases because of - this wilderness character, there is pressure to allow for increased resource use and development throughout the St. Elias region (Slocombe, 1992; YTG, 1992; Jarvis and Galipeau, pers. comm., 1997). Yet incremental changes in land use and development could have significant impacts on the ecological integrity of the region's protected areas, and activities carried out in one part of the region could have reverberations in other parts of the ecosystem (Hegmann, 1995). However, by implementing an integrated management effort that recognizes broad-scale ecological patterns and processes as well as shared resources, the opportunity exists to avoid such negative effects and maintain the region as an intact mountain wilderness, while still accommodating compatible human interests.

1.4 PROBLEM STATEMENT

While the size and number of protected areas in the St. Elias region have helped to maintain its wilderness character, these same factors - along with an associated complexity of management agencies and institutional arrangements - seem to have hindered cooperation between parks in the region. As noted by Slocombe (1996a), the challenge in maintaining the ecological health and integrity of the St. Elias region lies not in establishing new protected areas but, rather, in "integrating management of existing protected areas with each other, and with surrounding areas". However, the extent to which the protected areas of the St. Elias interrelate ecologically with each other and with their surroundings is not thoroughly understood. While the individual protected areas of the St. Elias have considerable information on the physical and biological features and processes that occur within their own borders, there has been no attempt to integrate this information with that from neighbouring areas to formally identify biophysical linkages and shared resources. As such, the relative extent to which a more integrated approach to managing the St. Elias region can be justified on ecological grounds remains unclear.

1.5 GOAL AND OBJECTIVES

In light of this problem statement, the goal of the study is to identify and characterize the broad-scale ecological features and patterns of the St. Elias region and, in turn, provide some assessment of the implications these have for management of the region - particularly as it relates to cooperation between parks and protected areas and adjacent unprotected lands. Several objectives have been identified to assist in meeting this goal:

i. Compile an extensive database on the biophysical nature and institutional setting of the St. Elias Region and build this database into an integrated geographical information system (GIS);
ii. Identify and describe existing cooperation and coordination between protected areas and surrounding land agencies in the St. Elias Region as well as shared management objectives and common management issues;
iii. Generate a regional biophysical synthesis of the St. Elias through integrative mapping and analysis for the purpose of identifying similarities and differences within the region as well as shared ecological features and processes and key linkages between its protected areas and adjacent lands; and,
iv. Analyze the synthesis with a view to assessing the biophysical basis for coordinating intergovernmental cooperation within a framework for ecosystem management - particularly as these activities relate to the conservation of biodiversity and maintenance of ecological integrity.

1.6 ANTICIPATED RESULTS

1.6.1 Regional Ecology and Management Implications

A preliminary evaluation of previous studies by various authors suggests that several significant biophysical linkages exist among protected areas of the St. Elias Region and that these have important implications for management cooperation and coordination. For example, it is anticipated that this study will affirm the ecological importance of low elevation valleys at a regional scale. Valleys such as those occupied by the Copper and Alsek rivers cut across the Chugach and St. Elias mountains and appear to act as corridors for the movement of biodiversity between interior and coastal areas (Klein, 1965). Similarly, it is probable that transboundary wildlife populations exist throughout the region, and serve to further link the region's protected areas with each other and with adjacent lands.

In light of such anticipated trends, it is envisioned that an integrated approach to coordinate and improve interagency management cooperation may be necessary to ensure the ecological integrity and health of this wilderness over the long term. However, the relative extent to which this should occur is unclear at this point. Certainly an approach which recognizes the diversity and complexity of the region would be necessary but such an approach must also recognize the ecological linkages that act to bind the region. It is anticipated that the results of this study will provide additional information for regional decision making, planning, and management, and shed light on appropriate frameworks for carrying out such integration and coordination.

1.6.2 Study Value and Significance

For the purpose of discussion, the significance of this study is divided into two areas: practical utility and academic value. Practical utility refers to the value of the study as an applied research project - that is, its usefulness within the St. Elias region. Academic value refers to the broader application of the study - that is, its applicability to other geographic regions and its contribution to knowledge in general. As the study is applied in nature, it is expected to have a considerable practical utility. First, considering the disjunct character of information in the St. Elias region, there is a definite need for its consolidation. Research results are expected to advance the state of ecological knowledge in the region by providing a better and more complete understanding of how the parks of the St. Elias interrelate with each other and with their surroundings and by illuminating broad-scale ecological patterns not visible at finer scales. Such knowledge will promote thinking at a regional level and could provide valuable information to assist in decisions of transboundary nature. Furthermore, analysis and assessment of the biophysical synthesis is expected to provide meaningful insight as to how environmental planning and resource management should proceed in the St. Elias.

Practical benefits such as these are evident in the Greater Yellowstone Ecosystem where a joint exercise undertaken by the US National Park Service and the US National Forest Service aggregated biophysical information from across the region and presented it in the form of a series of integrative maps and charts which were analyzed to assess the ecological features and processes which transcended administrative boundaries (Greater Yellowstone Coordinating Committee, 1987). Since that time, significant efforts have been made by both public and non-governmental agencies to develop an integrative, ecosystem-based approach to managing the Greater Yellowstone Ecosystem based on the regional patterns and ecological linkages identified in the original study (Miller, 1996).

In addition to this practical significance, it is anticipated that the study will also have a more general or academic value. Spatially, the St. Elias region contains the largest conglomerate of protected areas in the world and is, administratively, one of the most complex. Its ecological diversity and varied terrain add further to this regional complexity. It follows then, that if this type of study can be undertaken successfully in the St. Elias region, it can be employed in other similar frontier regions. As illustrated in the Greater Yellowstone region, such relevance can be extended beyond frontier regions to other wilderness areas where different management agencies share regional jurisdiction. Furthermore, it is expected that this study will be of benefit to other transborder protected areas and will contribute to an emerging literature in this area.

Finally, this study is also expected to yield methodological benefits in the area of information integration and synthesis, which is gaining increased recognition as a valuable component of ecological science and environmental management (e.g. Slocombe, in press; NCEAS, 1998; Baskin, 1997; Stewart, 1996). In light of the fact that a diverse set of information will be integrated from a wide variety of sources, the process of data collection, synthesis, and analysis utilized in this study should contribute to identifying and refining methods for interdisciplinary projects focussing on regions of similar scale and/or geography.

1.7 THESIS STRUCTURE AND OUTLINE

The organization of chapters in this thesis roughly follows the objectives listed in Section 1.4. Chapter Two provides the context for the study by summarizing relevant literature in the fields of conservation and regional ecology, regional-scale conservation planning and management, and transborder protected areas, as well as providing a background on regional ecological synthesis and analysis. The research process as well as methods and tools used in the study are described in Chapter Three.

Chapters Four and Five comprise the synthesis portion of the thesis. Chapter Four describes the institutional environment of the protected areas of the St. Elias including respective planning and management frameworks, history of establishment, zoning, land use patterns, and the relative level of protection offered by each. This chapter also details existing management cooperation between the protected areas and with adjacent lands and identifies commonalities and differences between the parks. Chapter Five characterizes the regional biophysical environment of the St. Elias region by way of a series of analytical maps detailing the regional tectonic and geological framework, physiography, climate, and hydrology. It then characterizes the regional biological environment by synthesizing information in the three areas of ecosystems, species diversity, and wildlife ecology through a series of written descriptions, maps, charts, tables and figures.

Chapter Six presents an analysis of the broad scale ecological patterns and processes evident from the regional biophysical synthesis and assesses the regional character of the St. Elias Mountain Parks. Chapter Seven, assesses the implications of the information presented in the preceding three chapters for ecosystem-based management of the region with an emphasis on coordinating cooperation between the region's protected areas and adjacent lands. Finally, Chapter Eight provides a summary of the thesis, a general assessment of the state of information in the St. Elias region, and suggests avenues for further research.

CHAPTER TWO
LITERATURE REVIEW

2.1 INTRODUCTION

This thesis draws from knowledge and experience in a wide variety of fields, including conservation biology, landscape and regional ecology, parks and protected areas planning and management, and landscape and regional ecosystem based management. This chapter provides a review of relevant literature in these fields, in turn providing a context for this study and demonstrating its relevance to environmental planning and management in a broad sense. Moreover, it draws links between these fields and illustrates the potential for transborder protected areas to act as focal points in facilitating ecosystem-based management in border regions.

2.1.1 Protected Areas and Sustainability

Prior to the main body of the literature review, two basic concepts fundamental to this thesis require some elaboration. First, this study proceeds under the recognition that environmental degradation as a result of past and present human activities is widespread, and that strategies for improving environmental quality and minimizing further degradation are basic necessities for ensuring a sustainable future. Secondly, and perhaps most pertinent to the research at hand, the study is rooted in the premise that protected areas are necessary and vital components of such strategies.

While this thesis focuses on the role of protected areas in achieving a sustainable future, it is explicitly recognized that they are only one component of the overall approach required to guide future inhabitation of the planet. Ultimately, no matter how many solutions are provided by ecology and conservation science, they must be accompanied by an economic, social, and political will to shift towards a sustainable, conserver society. As Meffe and Carroll (1997) state: "Unless major changes can be made in the way that humanity does business with the natural world, and in humanity's destructive patterns of population growth and resource consumption, it would appear that much of our biological knowledge of conservation will be rendered useless under the sheer weight of the human presence" (pg. 6).

2.1.2 Wilderness and Ecological Integrity

The terms *wilderness* and *ecological integrity* are used frequently throughout this thesis, and it is necessary to outline the link between the two terms. While not new, the term ecological integrity has seen a substantial growth in recent years and there has emerged a significant literature on its meaning and its value as an objective for environmental planning and management (e.g. Woodley *et al.*, 1993). Definitions of ecosystem integrity are varied and numerous and many are vague or "slippery" in nature (Noss, 1995). Yet most definitions seem to incorporate notions such as health, diversity, stability, resilience, naturalness, and wholeness, and - in a North American context - often refer to presettlement landscapes as ultimate models of ecological integrity.

In contrast, the term wilderness has a long and varied history. It has been used to describe a physical area, a conceptual terrain, and both simultaneously (Dubasak, 1990).

Today it is typically used to describe relatively large areas where resource extraction is absent, where human activity is minimal and where ecological processes are essentially uninhibited by human land use (Rosenberg, 1994). The ecological and social values of such areas have been extolled by innumerable authors and this is the context in which the word is used in this thesis.

While the concepts of wilderness and ecological integrity may have similarities, they are not the same. Yet the link between them is obvious. If the maintenance or restoration of ecological integrity is adopted as a guiding objective in environmental planning and management, then wilderness has a high value. Similarly, if an area is to be managed as wilderness, then it is probable that such an area will have a high level of integrity. This linkage is particularly important in the St. Elias region, which is generally considered to have a high level of integrity because large areas of wilderness remain.

Despite the connection between the two concepts, the scientific foundation for wilderness preservation has not always been explicit. As discussed by Soule and Noss (1998), the original protected area paradigm in North American - referred to as *monumentalism* because of its emphasis on protecting places of extraordinary natural beauty - evolved into the wilderness movement as it shifted towards “a belief in the intrinsic value of self-willed nature” (Nash, 1989, paraphrased in Soule and Noss, 1998). The other major movement in protected area designation to have emerged in North America - the science-based paradigm - has incorporated components such as biological conservation and ecosystem representation with an emphasis on concepts such as biodiversity and ecological integrity.

Given that it utilizes a rational scientific approach to natural area protection, it is perhaps not surprising that the science-based protected area paradigm has become predominant in the latter part of this century. In turn, the notion of wilderness has been criticized on many fronts (see Butler, 1998 for a discussion). Yet, as Soule and Noss argue, the two approaches are not competing but, rather, complementary. As illustrated in the literature reviewed in this chapter, conservation science is affirming the benefits of large wilderness areas in preserving biodiversity and maintaining ecological integrity. It is increasingly apparent that, as Foreman (1998) states, “science-based Nature reserve design does not come to bury traditional Wilderness Area designation, but to marry it”.

2.2 CONSERVATION ECOLOGY AND PROTECTED AREAS

As mentioned in Chapter One, there is a notable degree of overlap between conservation biology and landscape ecology, and the boundary between the two disciplines is vague when considering their implications for biodiversity conservation. Given this overlap, the two are collectively referred to here as *conservation ecology*. This section reviews the implications that both applied and theoretical research in conservation ecology have for the design of parks and protected areas. It then describes several of the approaches to planning and management that have been proposed to address the difficulties parks and protected areas encounter in preserving biodiversity and ecological integrity. For additional reference, a glossary of the conservation ecological terms and concepts used in this section is included in Appendix A.

2.2.1 Reserve Theory and Political Reality

While the development of principles or "laws" of conservation ecology has been advocated, it has also been suggested that it may be both unrealistic and dangerous to promote such principles because of the variability amongst, and complexity associated with, ecological systems (Harrison, 1994; Doak and Mills, 1994). Soule (1987) considered both arguments and concluded that :

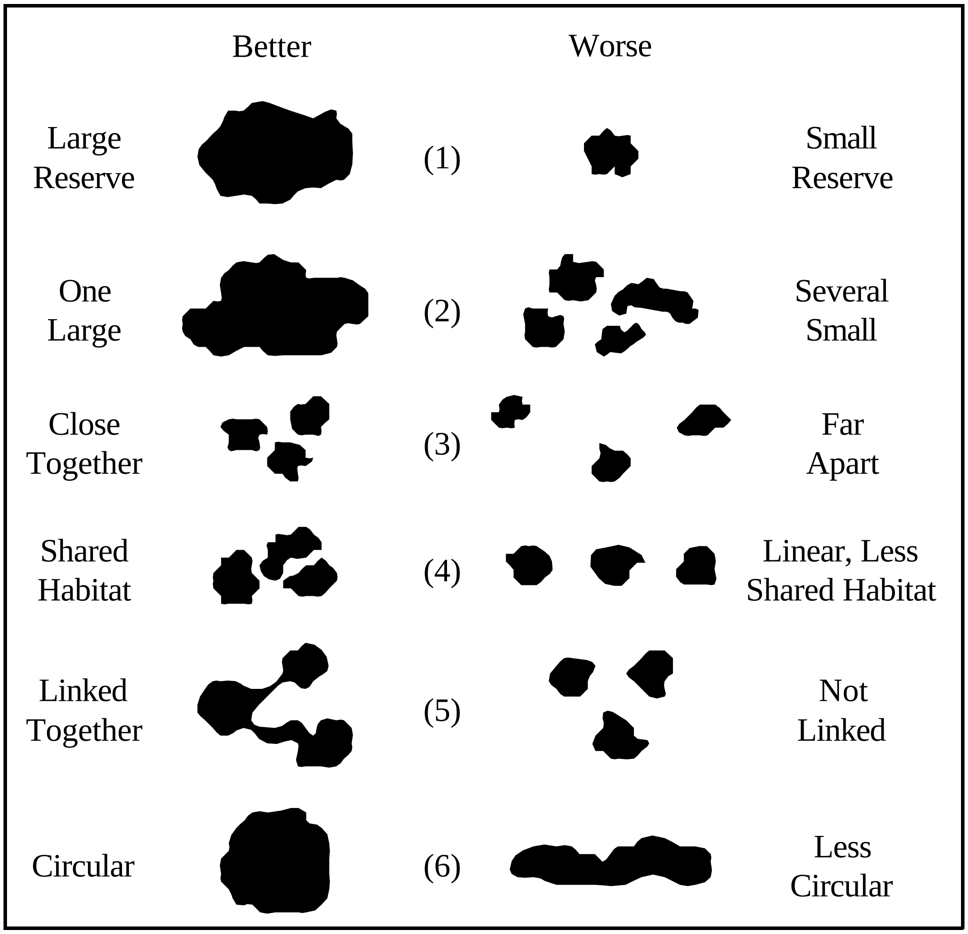
> "Administrators, policy makers, and managers have a right to ask for the bottom line...And biologists have the right and sometimes the obligation not to give an oversimplified, misleading answer to such a question... Nevertheless, I think that scientists owe it to the rest of society to provide rules of thumb, even when they know that sometimes the rules will be misunderstood and misused" (pg. 175).

It is, however, apparent that there are a number of generalizations that can be drawn from conservation ecology for the design of protected areas. Using the species area relationship (Connor and McCoy, 1979) and the theory of island biogeography (MacArthur and Wilson, 1967) as a basis, Diamond (1975) developed the set of principles for reserve design presented in Figure 2.1. Despite some criticism, particularly with respect to the second principle, Diamond's principles have provided a framework for protected area design that continues as a benchmark today (Meffe and Carrol, 1997; Primack, 1993).

Foremost among Diamond's reserve criteria is a principle that has been verified time and again as the most basic tenet of protected area design: that reserves should be as large as possible, wherever possible. Large protected areas have a higher probability of protecting biodiversity across all scales and attributes (Noss and Cooperrider, 1995; Noss, 1990), maintaining viable wildlife populations (Wilcox, 1984; Soule and Simberloff,

Figure 2.1: Island Biogeographic Principles of Reserve Design

Following MacArthur and Wilson (1967), Diamond (1975) proposed these principles as a basis for protected area design. Originally proposed by as a basis for including maximum species richness, these principles have been extended as a basis for maintaining metapopulation dynamics between reserves.
(Redrawn from Primack, 1993.)



1986), accommodating a broad range of ecological processes and functions such as natural disturbance regimes (Pickett and Thompson, 1978; Borman and Likens, 1979; Pickett and White, 1985) and metapopulation dynamics (McCullough, 1996; Hanski and Gilpen, 1991), and encompassing entire ecosystems and/or species ranges or territories (Grumbine, 1992). In short, the larger the protected area, the better its ability to preserve biodiversity and maintain ecological integrity.

Despite the support for large reserves, it is an unfortunate reality that relatively few protected areas are large enough to preserve biodiversity at all levels. For example, in a study of eight large protected areas in west central North America, Newmark (1985) calculated that each area was at least six times smaller than that required to support a population of 500 of its largest native carnivore. Only one contiguous area - the four Canadian Rocky Mountain National Parks - was large enough to support a minimum viable population (MVP) of 50 (grizzly bears). Similarly, the numerous examples cited in Clark *et al.* (1996) illustrate the immense territories required for preserving large carnivores in North America. The disparity between the size of existing parks and protected areas and the area required to support viable populations of carnivores such as grizzly bears, gray wolves, cougars, and wolverines is immense (Paquet and Hackman, 1995). The implication of such calculations is serious: most parks and protected areas cannot support the long-term persistence of most large mammals and, therefore, "depend on the survival of nearby populations from which periodic immigration may occur" (Theberge, 1993, pg. 144).

The ecological problems associated with small reserve size extend beyond capability for maintaining viable populations. Given the large areas often affected by natural disturbances such as fire, it is unlikely that most protected areas even approach what might be considered a minimum dynamic area. For example, Shugart and West (1981) suggested that protected areas be 50 to 100 times larger than the maximum size of the typical natural disturbance an ecosystem experiences. This presents a serious dilemma in the case of small preserves where, as Noss and Harris (1986) state, "the shifting mosaic has virtually nowhere to shift, and the size of a typical disturbance patch may exceed that of the preserve itself" (pg. 300).

In addition to the size of many protected areas being inconsistent with ecological theory, the boundaries of most protected areas are often incongruent with the natural features they are trying to preserve. Furthermore, boundaries often represent an abrupt transition in land use, effectively isolating the reserve from other natural areas (Schonewald-Cox and Bayless, 1986). In many cases, the inconsistencies between ecological reality and administrative reality have caused significant stress on protected ecosystems and jeopardized preservation objectives. Examples of the stress of such incongruities are widespread, particularly with respect to mortalities of wildlife ranging outside protected areas (e.g. Forbes and Theberge, 1995; Knight and Eberhardt, 1985).

The corollary of such boundary troubles comes in the form of external impacts on protected areas. Just as human imposed boundaries cannot contain ecological processes, they also cannot preclude the negative impacts originating from human activities outside protected areas. On an increasing level, such impacts are being viewed as the most serious threat to ecological integrity in national parks and other protected areas (Stottlemeyr, 1987a). In addition to threats to park wildlife as a result of external human-caused mortality, such threats include impacts from adjacent land uses such as forestry and mining, water pollution and flow diversion or regulation, air pollution, and invasions of exotic species (eg. Kushland, 1987; Stottlemeyr, 1987b; Johnson and Carothers, 1987; Janzen, 1986).

The inconsistencies of many North American protected areas with ecological theory and on-the-ground reality should not be completely unexpected. The original goal or mission of North American park systems was "the preservation of scenic beauty and the protection of natural wonders so that they could be enjoyed by people" (Hales, 1989, pg. 139). As such, little attention was paid to preserving biodiversity or ecological integrity, and even less attention was paid towards ecological theory. However, given a shift in emphasis from recreation to preservation, a substantial literature has emerged that focuses on identifying criteria and methods for use in selecting and designing new protected areas for preservation goals (e.g. Noss, 1996a; Scott *et al.*, 1993; Soule and Simberloff, 1986; Diamond, 1975). The consequence of this body of literature has been the development of an extensive set of guidelines for the establishment of protected areas in a variety of circumstances and settings. While such approaches may not eliminate the disparity between ecological theory and "on the ground" political and social realities, they can help reduce it.

2.2.2 Greater Park Ecosystems, Biosphere Reserves, and MUMs

Ultimately, conservation biology and landscape ecology have demonstrated that, no matter what their size and shape, parks and protected areas cannot function as isolated entities. Their borders, while necessary, are human-defined constructs that cannot impound biodiversity nor exclude negative external impacts. Such areas must be managed within the context of their landscape ecological surroundings if they are to preserve biodiversity and retain a high degree of ecological integrity. It is for these reasons that the notion of greater park ecosystem (GPE) planning and management has emerged. Such an approach recognizes the need to consider areas beyond a park's boundary and focuses on maintaining and/or restoring ecological linkages with surrounding lands (Grumbine, 1992).

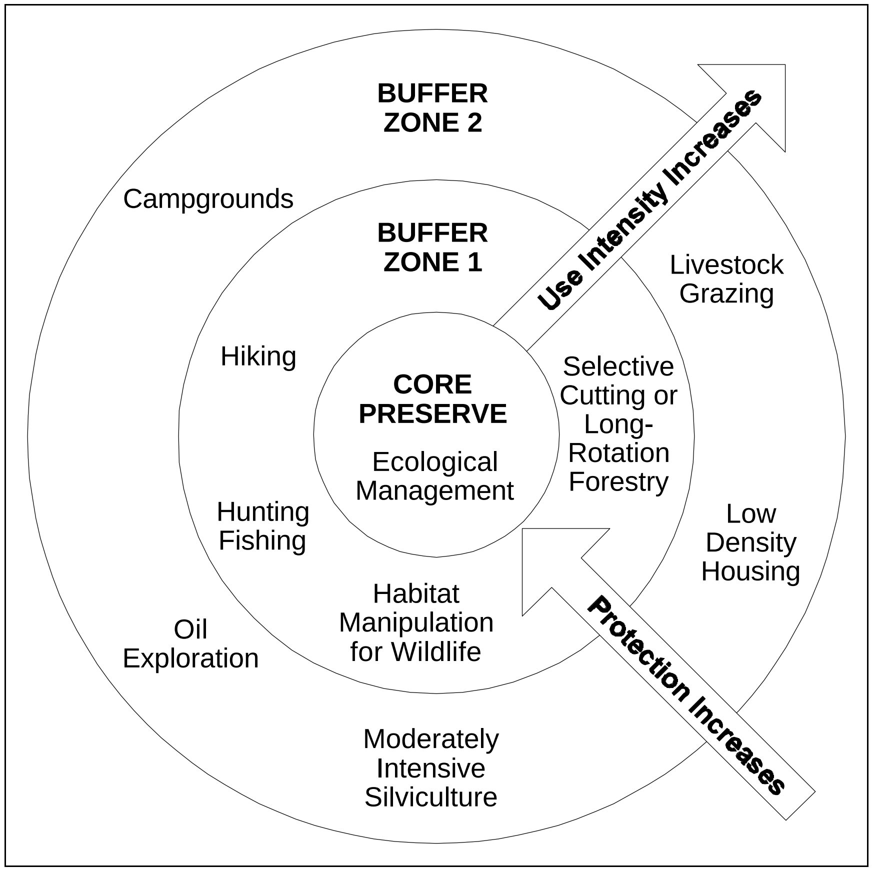
Greater ecosystems have been identified or conceptualized for a variety of protected areas in North America at a variety of scales (e.g. Clay and Deering, 1997; Keough, 1997; Skibicki and Nelson, 1997; Trembley, 1997; Skibicki, 1995; Keiter and Boyce, 1991). In addition to such geographical conceptualizations, plans or strategies have been proposed for several protected areas to foster coordinated environmental planning and management across their greater ecosystem. Objectives of such strategies often include the establishment of "buffers" around protected areas and the preservation, restoration, and/or maintenance of corridors and linkages between a protected area and other nearby natural areas. Facilitating such linkages beyond the scale of the individual protected area, or several areas in immediate proximity (i.e. protected area "networks"), is discussed in the next section.

Despite the recent (i.e. past 10 years) emergence of "greater park ecosystems", the notion of integrating a protected area with its surroundings has its roots in the biosphere reserve, developed over 25 years ago as part of UNESCO's Man and the Biosphere (MAB) Program (Batisse, 1982). Sensing the need to provide a "clearly defined territorial and logistical base for MAB activities" (Batisse, 1982), UNESCO developed the concept of establishing a global network of protected areas as a basis for conservation and research. These "biosphere reserves" were to consist of a strictly protected core area with little human interference, a regulated buffer zone or "zone of cooperation" surrounding the core area where traditional renewable resource and land use activities would occur, and a less restrictive second buffer zone or "transition zone". The first biosphere reserve was designated in 1976 and today there are 337 biosphere reserves in 85 countries world-wide (UNESCO, 1996)

The three primary objectives of biosphere reserves often cited are: (i) to conserve the diversity and integrity of natural and semi-natural ecosystems for present and future use, (ii) to provide areas for ecological and environmental research, including baseline studies, both within and adjacent to the reserve, and (iii) to provide facilities for both education and training (Batisse, 1982). Over the years, the role of biosphere reserves has evolved into providing an international model for sustainable development with particular emphasis on local participation and integration of protection objectives of the core with the socio-economic landscape of the outer buffer zones (Miller, 1996).

A model that seems to have evolved from the Biosphere Reserve approach is the multiple-use module or "MUM". As illustrated in Figure 2.2, the MUM model also incorporates a strictly protected core combined with multiple buffer zones. The MUM concept was developed by Larry Harris in 1984 and first applied in theory to the preservation of stands of old-growth Douglas Fir (*Pseudotsuga meziesii*) in the western Cascades of Oregon (Harris, 1984; Noss and Harris, 1986). As summarized by Noss and Harris (1986) the plan called for "surrounding each existing old-growth island by a long-rotation management area, and interconnecting these areas by means of riparian corridors and other linkages" (pg. 305). The concept was refined by Noss and Harris (1986) and Noss (1987) as a model for preserving biodiversity at all scales and overcoming the

Figure 2.2: The Multiple Use Module (MUM) Model
(redrawn from Noss, 1987)



drawbacks of small, isolated protected areas in fragmented landscapes.

The MUM model has both similarities and differences with the Biosphere Reserve approach. Like Biosphere Reserves, MUMs consist of a well-protected core area "surrounded by buffer zones of centrifugally increasing utilization by man" (Noss and Harris, 1986). However, unlike the Biosphere Reserve approach, the core area of a MUM can focus on preserving diversity at any level in the biological hierarchy and, therefore, can vary immensely in scale (Noss and Harris, 1986). Finally, the objective of attaining social and cultural integration that is associated with the biosphere reserve model is more or less absent in the MUM model. Instead, emphasis is simply placed on ensuring adherence to the land uses permitted within each zone.

2.2.3 Reserve Networks

Another generalization to emerge from conservation ecology is the need to reconnect protected areas where continuous habitat once existed or, at the very least, to ensure that landscape connections between protected areas do not become inhospitable to the movement of biodiversity. Such connectivity facilitates immigration and emigration and can serve in maintaining species dispersal and migration patterns. Just as MUMs and biosphere reserves can assist in relieving some of the troubles associated with inadequate size of protected areas, "reserve networks" can assist here. Noss and Cooperrider (1995) further describe the concept and its rationale:

> "If functionally connected, a system of reserves may be integrated into a whole that is greater than the sum of its parts. Although no single reserve may be able to support a long-term viable population of a species with large area requirements, such as cougar or grizzly bear, reserves linked by corridors or other avenues of movement may do so. Thus, whereas individual reserves are unlikely to encompass ecosystems replete with all native species, a well-connected network of reserves just might" (pg. 144).

One of the leaders in the movement for reserve networks is conservation biologist Reed Noss of Oregon State University. Noss's 1983 article in *BioScience* "A Regional Landscape Approach to Maintain Diversity" prompted a significant amount of thought on the role of landscape and regional approaches to biodiversity conservation. He urged an expansion of conservation concern beyond the scale of the local ecosystem, emphasizing protection of regionally significant habitat wherever it occurred, a complex of large and small protected areas, and broad corridors of natural habitat to connect reserves (Noss and Cooperrider, 1995). Since then, Noss has continued to contribute to this area with numerous academic and popular articles and technical reports advocating the use of the reserve network model and illustrating its ecological bases.

What is apparent about the reserve network model is its adaptability. It can be used as a basis to connect existing reserves, as a foundation for designing new reserves, or a combination of both. As illustrated in Figure 2.3, the model can be applied to highly fragmented, human dominated landscapes as well as wildlands. Finally, networks can range from landscape to global in scale. Perhaps the most famous of these is the "Yellowstone to Yukon" conservation initiative; an innovative and visionary proposal to establish and maintain habitat linkages between protected areas in the Rocky Mountains to facilitate the movement of biodiversity in western North America (Harvey, 1998, Locke, 1997).

2.2.4 Transborder Protected Areas

Several terms have been used to describe protected areas that cross national boundaries, including transboundary parks, international peace parks, transfrontier nature reserves, and cross border parks (Danby, 1997). While the terminology may differ, the concept is the same: parks and protected areas across from each other at a common political border or single protected areas that cross political boundaries. Thorsell and Harrison (1990) present the results of the first inventory of these areas and identified a total of seventy sites

Figure 2.3: The Reserve Network Model and its Inversion

(Redrawn from Noss, 1995.)

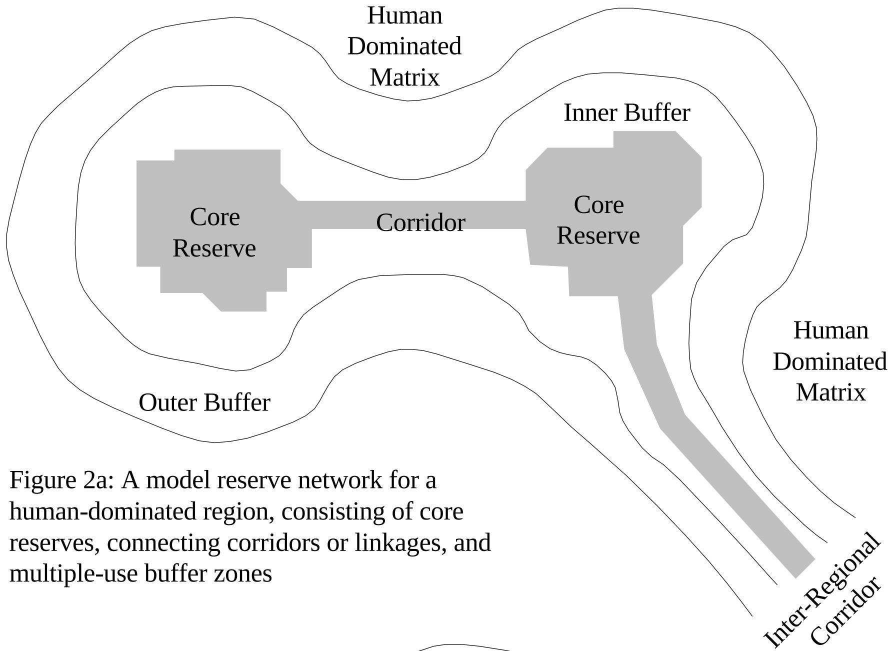


Figure 2a: A model reserve network for a human-dominated region, consisting of core reserves, connecting corridors or linkages, and multiple-use buffer zones

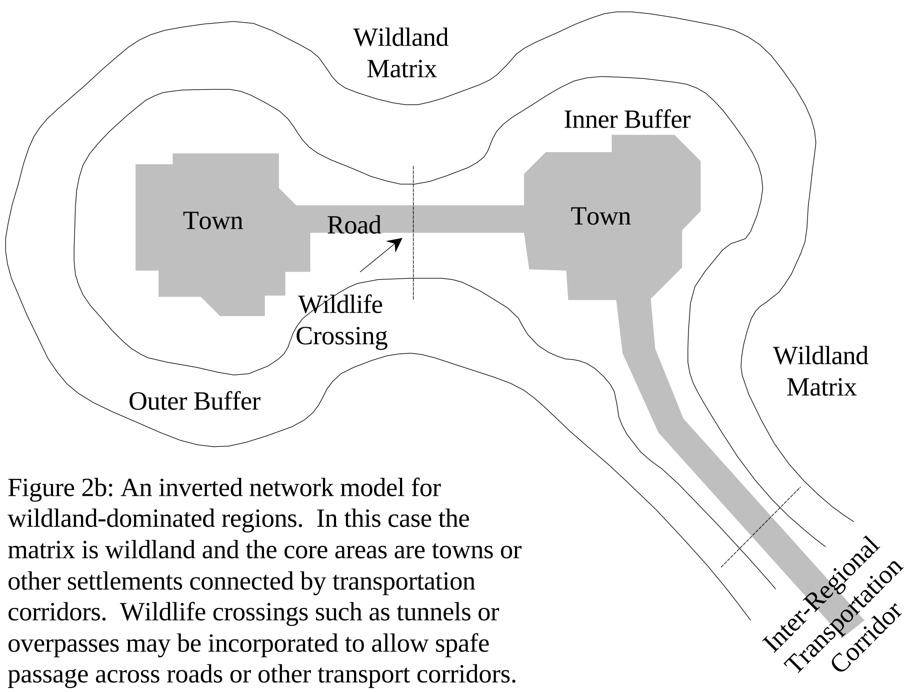


Figure 2b: An inverted network model for wildland-dominated regions. In this case the matrix is wildland and the core areas are towns or other settlements connected by transportation corridors. Wildlife crossings such as tunnels or overpasses may be incorporated to allow spafe passage across roads or other transport corridors.

involving 65 countries. A more recent examination by Zbicz and Green (1997) identified 136 sites worldwide involving 98 countries. There are currently six transborder parks meeting the IUCN definition of a protected area along the Canada-United States border. One of these - Waterton Lakes National Park in Alberta (est. 1895), and Glacier National Park in Montana, USA (est. 1910) - is generally recognized as the first international transborder protected area.

Given that size and connectivity are important factors in determining the success of an area in protecting biological diversity, the formation of a transborder protected area will usually have ecological benefits beyond those associated with the individual parks in isolation (Danby, 1997). Foremost among these is the chance that the transborder protected area will protect an entire ecosystem or watershed crossed by an international border and, thus, the key geological, hydrological, ecological, biological, and evolutionary functions and processes that occur across a landscape (Danby, 1997).

Despite these benefits, literature in the field of conservation biology has not really explored the topic of transborder protected areas. A search of the two prominent journals *Conservation Biology* and *Biological Conservation* found only one article discussing transborder protected areas in general. In their 1993 paper, Dinerstein and Wikramanayake (1993) advocate the use of transborder reserves to maintain species diversity in areas where numerous small nations exist and one individual nation is incapable of preserving enough land for sufficient protection. The only systematic evaluation of transborder reserves comes from Soule *et al.* (1979) and a follow-up study by Burkey (1995) who demonstrate that the adjoinment of Serengeti National Park and

Masai Mara National Reserve in Tanzania and Kenya improves the ability of these areas to maintain populations of large African mammals.

2.3 APPLYING CONSERVATION ECOLOGY AT REGIONAL SCALES

2.3.1 Regions and the Land Hierarchy

The ecosystem concept can be traced back to Arthur Tansley who first used the term in 1935 to describe a complex of organisms and the abiotic factors that affect it (R. Smith, 1986). Since Tansley, the concept has traditionally been associated with a local scale (Slocombe, 1993). However, the ecosystem concept is increasingly being applied at any given scale, as attested in Agee and Johnson's (1988) definition as "any part of the universe chosen as an area of interest, with the line around that area being the ecosystem boundary and anything crossing the line being input or output" (pg. 4-5). A similar perspective is taken by Odum (1986), who stated that ecosystem boundary delineation can take any scale, as long as the system is conceived as being open, and inputs and outputs are recognized.

If the earth is perceived as one large ecosystem, it follows then that it can be subdivided into smaller ecosystems which, in turn, can be further subdivided. Each of these subdivisions is termed a *domain of scale* in a spatial land hierarchy (Forman, 1995). A land hierarchy proposed by David Miller in 1978 has gained widespread acceptance, and includes three basic domains of scale. The *local ecosystem* is the finest of the three and is mapped at the site scale, usually in the range of 1:10,000 to 1:100,000 (Bailey, 1987). From a human perspective, it is relatively homogenous and often distinct in its boundary.

Examples may include a forest patch, a lake, etc. The next domain in the hierarchy is the *landscape mosaic*, mapped at a scale ranging from 1:250,000 to 1:1,000,000 (Bailey, 1987). Landscape mosaics are comprised of a mix of local ecosystems repeated in a similar form over a broad area. Common geology, land forms, soils, vegetation types, and human land uses serve to unify the area (Miller, 1978). The broadest domain described by Miller is the *region*, mapped at scales generally in the range of 1:1,000,000 to 1:3,000,000 (Bailey, 1987).

While the concept of the ecological region is widely accepted, the factors used to identify and delineate them vary greatly. Yet, it is apparent that two overriding factors are common to all definitions: a region is a large spatial area - usually in the range of thousands to hundreds of thousands of km^2 - that exhibits one or more dominant influences that serve to unify all areas within it. Quite often these influences are identified as a common macroclimate, topography, and sphere of human activity (Forman, 1995). Given the land hierarchy it is a part of, a region will contain several landscape mosaics as well as the patches, corridors, and matrices that they are comprised of. While it will not exhibit a repeated pattern of landscapes, "the spatial pattern or arrangement of landscapes in a region is just as important functionally as the pattern of continents on the globe, local ecosystems in a landscape, or gaps within a woods" (Forman, 1995, pg. 25).

A more detailed - and specific - approach to delineating components of the spatial land hierarchy is ecological land classification (ELC); an integrative method of classifying ecosystems in nested groupings of definable units (Sims *et al.*, 1996). Examples of this approach are widespread (see Sims *et al.*, 1996, for a review) although not necessarily compatible due to methodological differences. For example, the Canadian classification (Wiken, 1986) utilizes four levels: ecozones, ecoprovinces, ecoregions, and ecodistricts, and uses differences in geomorphology, soils, vegetation and climate equally to delineate areas. The American classification (Bailey, 1995) uses three levels: domains, divisions, and provinces, and places heavy emphasis on climate to delineate these areas.

2.3.2 The Region as a Unit for Implementing Conservation Strategies

In light of the theories and principles of conservation ecology, it is evident that ecological planning and management must occur at broad ecologically-based scales in order to sustain biodiversity and ecological integrity. For both ecological and institutional reasons the region is quickly becoming accepted as the most appropriate scale for carrying out such conservation strategies (e.g. Noss, 1983; Grumbine, 1992; Davis, 1992; Skibicki, 1995; Miller, 1996). Noss (1992) best summarizes why:

> "It is the scale of a constellation of national forests, parks, and surrounding private lands, or of a large watershed or mountain range. The regional landscape is big enough to comprise numerous, interacting ecosystems; to incorporate large natural disturbances; and to maintain viable populations of large, wide-ranging animals. Yet it is small enough to be biogeographically distinct, and to be mapped in detail and managed by people who know the land well. It often has cultural significance and coherence as a 'bioregion' " (pg. 241).

Forman (1995) also endorses the use of such broad areas as a basis for environmental planning and management and states that "to accelerate the use of ecology in design, planning, conservation, management, and policy, we must use regions and landscapes that balance and integrate natural processes and human activities"(pg. 14).

Based on the need to maintain viable populations of large vertebrates, Salwasser *et al.* (1987) identified several regions in the United States where regional biodiversity conservation strategies could be implemented. As illustrated in Figure 2.4, the regions are continuous areas dominated by public land, primarily national parks, national forests, and national wildlife refuges. They termed these areas *regional conservation networks* and proposed agreements among the respective government agencies for the fundamental purpose of creating "a combined area large enough and with sufficient level of coordinated protection to sustain the focal species as well as the integrity of the entire ecological system" (pg. 166-167).

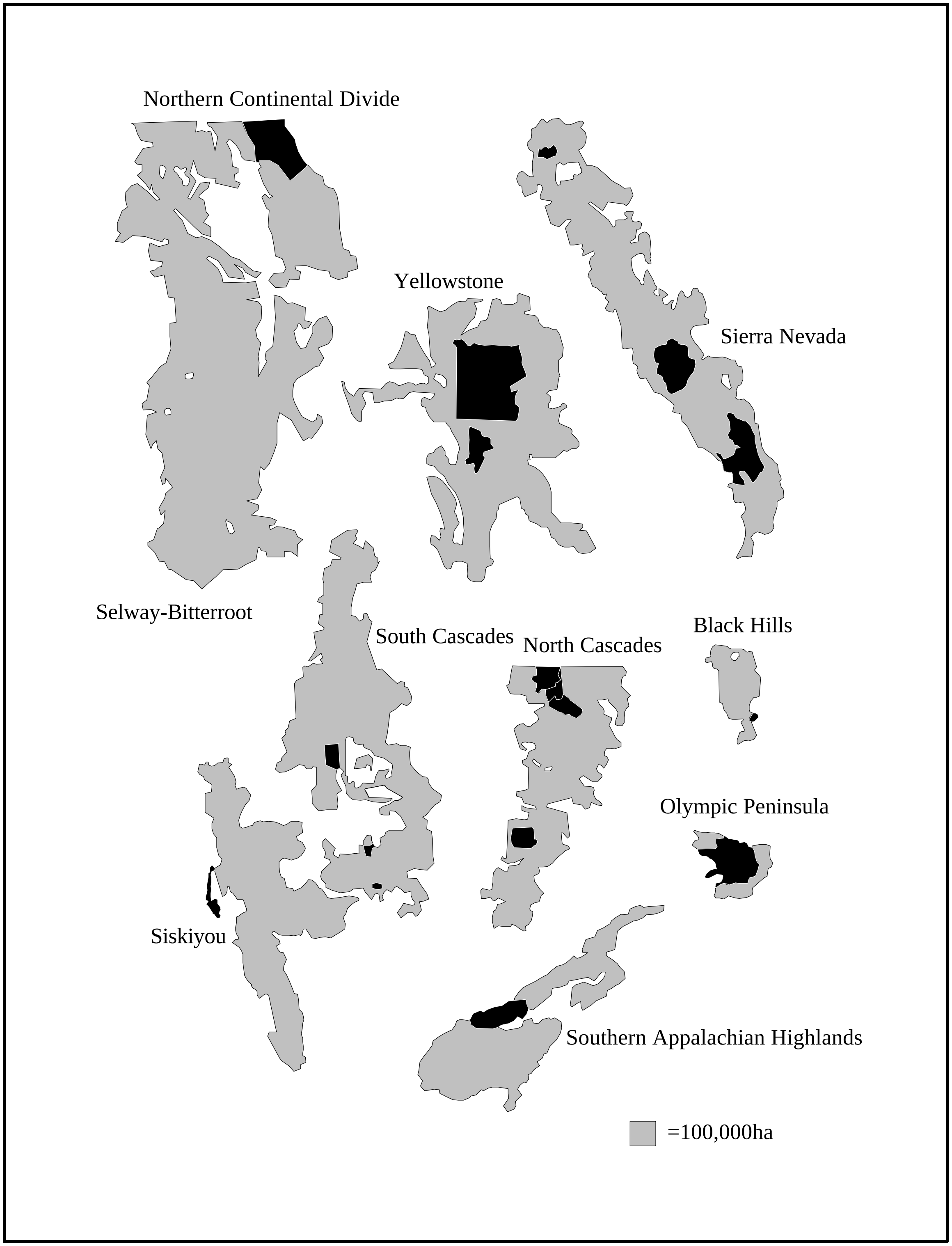
To illustrate the effect of these hypothetical regional networks, Salwasser *et al.* evaluated their ability to protect populations of large carnivores by comparing their total combined area with that required to sustain a census population size of 500, 1000, and 2500 individuals. Using previously published species-area requirements for each region's largest carnivore, their results suggested that only one area - the 7,535,000 ha Selway-Bitterroot region - would be large enough to support a census population of 2,500 individuals. However, the results indicated that - based on area alone - 8 out of the 10 regional networks could sustain a population in excess of 1000 individuals, and could sustain populations far in excess of what the core protected area(s) was capable of on its own.

2.3.3 Ecosystem Management

Over the past decade, ecosystem management has risen to become the predominant model

Figure 2.10: Outlines of Ten Potential Conservation Networks in the USA

National parks are shown in black. Other public lands offering protection - primarily national forests, national wildlife refuges, and national monuments, are shaded grey (Adapted from Salwasser *et al.* 1987).



in environmental planning and management. It is now incorporated into official policy for many public land management agencies (e.g. US National Forest Service, Parks Canada), and exercises in land use planning increasingly claim to use "an ecosystem approach". Perhaps most relevant to this thesis is a growing body of literature advocating the application of ecosystem management to parks and protected areas to reduce internal and external threats and assist in regional integration (e.g. Agee and Johnson, 1988; Agee, 1996). Furthermore, ecosystem management is being advocated as the foundation for integrating the sciences of conservation biology and landscape ecology into environmental planning and management at regional scales with a view to sustaining biodiversity and ecological integrity over the long term (e.g. Knight, 1998; Urban, 1993).

In spite of this widespread support, definitions of ecosystem management vary greatly. Yet, most definitions are rooted in the notion of enlarging the focus of land management and resource conservation to incorporate entire ecosystems, rather than individual components (Salwasser and Pfister, 1993). Such an approach appears to be rooted in the extra-local causes of many environmental problems, the complexities and interconnections associated with ecological systems, and a recognition that human designated jurisdictions often do not conform with ecological reality.

Edward Grumbine's 1994 paper "What is Ecosystem Management?" has become a widely referenced paper on the subject. Noting that a lack of agreement had created some confusion, Grumbine analysed peer reviewed papers on ecosystem management to determine where agreement did exist. Ten dominant themes emerged from this review, each being an attribute that various authors had identified as "critical to definition, implementation, or comprehension of ecosystem management" (Grumbine, 1994, pg. 29). These included: (i) use of a hierarchical approach and systems perspective; (ii) use of ecological boundaries; (iii) ecological integrity as an overriding goal; (iv) improving information bases through scientific research and data collection; (v) increased levels of monitoring to track management actions; (vi) use of an adaptive management approach; (vii) cooperation amongst agencies and stakeholders; (viii) structural and managerial institutional change; (ix) recognition that humans are integral ecosystem components; and, (x) recognition that human values guide management goals.

In a similar manner, the Keystone Center of Colorado brought together members from a diverse field of government agencies, non governmental organizations, universities, and industries in a "National Policy Dialogue" in an attempt to refine the concept of ecosystem management. Participants arrived at a consensus on a number of key elements for use in implementing ecosystem management and identified five central goals that ecosystem management processes should seek to achieve (Keystone Center, 1996):

i. Maintain ecosystem integrity;
ii. Sustain biodiversity and ecosystem processes at a regional scale;
iii. Sustain vibrant, livable, and economically diverse human communities;
iv. Incorporate distinct community and stakeholder values in the design and implementation of ecosystem management initiatives; and
v. Integrate the ecological, economic, and social goals of stakeholders.

2.3.4 Cooperation in Regional Ecosystem Management

Given the size of regions, the complexity of land use, ownership, and jurisdiction often associated with such areas, and the fact that ecosystems invariably transcend political and administrative boundaries, it is apparent that cooperative efforts are key in facilitating ecosystem management. Most authors describe interagency cooperation and coordination as one of the most fundamental components of ecosystem management (e.g. Grumbine, 1997; Cortner, 1994; Grumbine, 1991; Gilbert, 1988; Salwasser *et al.*, 1987). While this need for interagency cooperation is not unique (see Alexander, 1993), ecosystem management certainly "intensifies the need for collaborative efforts among those with an interest or stake in land management" (Cortner, 1994, pg.229).

Salwasser *et al.* (1987) define two levels at which collaboration is necessary for effective conservation: among government agencies, and between agencies and private (non-governmental) groups. They then describe three general approaches to establishing such cooperation:

i. *Locally arranged, informal cooperation* is the most easily attained. However it is also likely to have only a small impact and, owing to "frequent changes that can occur in personnel, directives, and budgets" (pg. 163), be the least stable through time.

ii. *Formal agreements or memoranda of understanding* (MOU) are more difficult to obtain, requiring a great deal of preparation and negotiation as well as endorsement of top-level administrators. However, they are more likely to survive change and affect management activities.

iii. *Legislative acts mandating cooperation* are likely to be the most stable and produce long-lasting and broad results, "but usually require equally strong financial backing, public interest, and political support" (pg. 163).

Alexander (1993) and Cortner (1994) make similar distinctions based on formality of cooperation and identify similar advantages and disadvantages to each.

Despite its need, achieving effective cooperation remains one of the key challenges in implementing ecosystem management (Gerlach and Bengston, 1994; Cortner *et al.*, 1996). Varley (1988) sums up this issue in his discussion of Yellowstone National Park:

> "The lack of commonly held policy and management goals among the agencies remains the single greatest impediment to sound ecosystem coordination...The crushing complexity of coordinating management activities between scores of separate political and administrative entities looms as the second most important challenge" (pg. 220).

Several authors have commented on fundamental problems that must be resolved in order to overcome the challenge of improving cooperation. Gilbert (1988) offered the following:

> "Perhaps the main problem is that administrators and managers of agencies with specific mandates to manage natural resources, though they may recognize cooperation as necessary for dealing with most contemporary resources issues, are reluctant to relinquish any control. Cooperative activities require special interpersonal and managerial skills, yet training in these areas is insufficient. Cooperative agreements on specific issues are common, but there is little incentive or budget for planning broad, cooperative programs. As a result, natural resources are often treated and managed as isolated entities." (pg. 182)

In his analysis of USDI Park Service and USDA Forest Service relations, Grumbine (1991) argues that even where interagency cooperation has occurred, whether carried out under the axiom of ecosystem management or not, it has been largely unsuccessful. He cites the US Endangered Species Act, the Interagency Grizzly Bear Committee, and the US Man and the Biosphere Program - agreements that are often referred to as successful examples of interagency cooperation - as examples that actually "do not inspire much confidence" (pg. 31). Furthermore, Grumbine takes issue with the fact that cooperation is most often considered at the executive or intergovernmental level. As he notes, few professionals or even academics have connected cooperation with "the need for democratic, grassroots participation" (pg. 31). While this has changed somewhat in the seven years since his article, it remains applicable today. Yet thinking on cooperation must be extended to include local participation and consultation that involves nongovernmental organizations as well as individual citizens if ecosystem management is to succeed as a truly integrative approach.

2.3.5 Cooperation in Transborder Protected Areas

Border regions can be ideal locations for the establishment of parks and protected areas given their tendency to be low in population and economic activity (Herzog, 1991). Yet, transborder parks and protected areas are subject to the same internal and external threats as insular parks and protected areas and face the same operational challenges as these other areas. Collaborative management of transfrontier protected areas can and has been used to overcome these challenges in a variety of locations (Hamilton *et al.*, 1996).

The extent of transfrontier cooperation on any issue varies dramatically throughout the world. Most often it is a function of the relationship between the two nations, the seriousness of the problem(s) at hand, and the political will to resolve the problem(s). Von Malchus (1982) states that cooperation in frontier regions "may range from the exchange of information and the general harmonization of programs or individual schemes to joint problem analysis and the preparation of common policies for the development of certain frontier areas, including practical and financial measures for the implementation of such policies" (p. 214). Cooperation in the planning and management of transfrontier protected areas is no different. As noted by Hamilton *et al.* (1996), cooperation can range from simple informal agreements involving only the staff of the individual parks, to complex formal agreements involving numerous agencies and organizations, governmental and otherwise. For the most part however, initiatives are more often of the less formal type.

Few transborder protected areas have achieved or even desire to achieve complete integration of management activities; primarily because the majority of them have not been created intentionally (Danby, 1997). Nevertheless, most transborder protected areas do coordinate their activities to some extent. Where cooperation has occurred beyond simply communicating regularly, it has assisted in controlling poaching and wildfires, provided for the sharing of information and technology between the two parks, provided a forum for joint staff training and staff exchanges, improved the protection and maintenance of wildlife, coordinated research efforts and tourism strategies, and encouraged sustainable development of border regions within national planning systems (Hamilton *et al.*, 1996; McNeely, 1993).

One of the better known examples of cooperative management occurs between Parks Canada and the US National Parks Service at the Waterton-Glacier International Peace Park. While the two parks are administratively separate, they share such responsibilities as search and rescue operations, law enforcement, and interpretive publications and hikes. The two parks also exchange staff regularly, conduct joint meetings, and "generally coordinate their work towards common, long-term goals and objectives" (Lieff and Lusk, 1990, p. 47). Attempts at further coordinating park management are focussing on establishing a single visitor's fee, developing common research programs and databases, and lobbying the International Boundary Commission to cease clearing the six-metre wide swath along the border between the parks (Lieff and Lusk, 1990).

Considering that most international borders do not conform to ecosystem boundaries, cooperation in the planning and management of lands surrounding transborder protected areas is an important task. While there is little experience in this type of cooperative planning and management, Zambia and Zimbabwe have taken strides towards such an approach. Victoria Falls, a World Heritage Site, is located on the border between the two nations. Recognizing the increasing pressure from tourism development around the falls, the governments of each country recently developed a bi-national team to carry out a Strategic Environmental Assessment (SEA) of these developments and develop a management plan for a 30 km radius around the falls. Based on the results of this process, both Zimbabwe and Zambia have agreed to reduce development around the World Heritage Site (Nalumino and Meynell, 1997). Other efforts towards this type of management have occurred at Waterton-Glacier where some coordination of World Biosphere Reserve activities and ecosystem-based management strategies has occurred (Hamilton *et al.*, 1996).

There are, however, several significant obstacles to achieving management cooperation. For example, the reinforcement of national sovereignty is often cited as a benefit of establishing a transborder protected area. However, local communities and even governments have often perceived the integrated management of these areas as a threat to national sovereignty. A recent proposal to integrate management of North Cascades National Park in Washington State with Manning Provincial Park in British Columbia and develop an ecosystem-based approach to managing surrounding lands, was met with firm resistance from local communities in the US who believed the plan to be an intrusion of the international community on the liberty of American citizens (Voorhees, 1996). Similarly, political leaders in Central America have expressed hesitancy at promoting binational parks "for fear that they are somehow relinquishing control of national territory" (Arias and Nations, 1992, pg. 55). Such apprehensions are, of course, intensified in cases where the relationship between two countries is strained. Although, as asserted by Weed (1994), Arias and Nations (1992), McNeil, (1990) and many others, one of the primary benefits - and even purposes - of transborder protected areas is the promotion or facilitation of peace between two countries by way of cooperation (thus the name “peace parks”).

A second obstacle to implementing cooperative management is the complexity of coordinating the governmental agencies involved and the various institutional arrangements that apply to them. This task is often difficult to achieve within a single nation, let alone between two separate nations. This difficulty is compounded when an ecosystem approach is proposed and additional government agencies and private landowners are involved.

Several authors have suggested that one of the largest stumbling blocks to achieving effective transfrontier cooperation is the lack of effective agreements between nations (e.g. McNeely, 1993; Von Malchus, 1982). For example, McNeely (1993) states that "To work well, transborder protected areas must have the appropriate institutional structures and, above all, legally-binding regulations and compatible legislation between the border countries" (pg. 155). However, several transborder protected areas have simple, informal agreements and experience with cooperation in these areas has been very positive (Hamilton *et al.*, 1996). This suggests that formal, binding agreements may not always be necessary. Instead, agreements should be tailored to the needs and desires of the parks, agencies, and governments involved. Moreover, as Weed (1994) notes, formal agreements may be important as guidelines, "but useless if unaccompanied by concrete action" (pg. 178).

2.4 REGIONAL ECOLOGICAL SYNTHESIS AND ANALYSIS

With few exceptions, most authors concur that the necessary first step in implementing regional ecosystem management is development of a picture of the ecosystem and how it operates. For example, Vogt *et al.* (1997) argue that the adoption of a systems perspective is the necessary first step toward planning for ecosystem management. The next phase in the development of ecosystem management they argue, "should be an ecological assessment of the specific system being managed" (pg. 115-116). Such an assessment should be undertaken with a view to: (i) organizing existing information in more useful or accessible configurations, (ii) identifying what new information is needed to inform management decisions, and (iii) aiding managers in setting and ordering management priorities (Vogt *et al.*, 1997). Skibicki (1995) lists three critical elements that require identification for development of any such picture: external or regional biological linkages, regional ecological processes, and human-induced stresses.

The assertions of Vogt *et al.* and Skibicki are key to this thesis as it aims to identify Skibicki's elements and meet the objectives of Vogt *et al.* for the St. Elias Mountain Parks. However, carrying out such an assessment at a regional scale can be an arduous and complicated task hindered by spatial scale, agency and actor complexities, and the sheer volume of information available. To aid in overcoming these hindrances, this study has adopted a methodological approach rooted in regional ecology that emphasizes mapping and spatial analysis at broad scales.

2.4.1 Regional Ecology and Related Fields

Ecological science has traditionally focussed on small or fine scales. In many ways, this is the result of a predilection amongst ecologists towards a reductionist, hypothesis-testing research approach (Brown, 1995). However, given the influence of the nonequilibrium paradigm in ecology (see Pickett *et al.*, 1992), combined with a growing recognition of emergent properties at successively higher levels of biological organization, "it is apparent that, more than ever, ecological studies must be pursued at many different levels, and on many different spatial and temporal scales" (May, 1994; pg. 2). Moreover, in light of the implications of conservation ecology for the preservation of biodiversity and ecological integrity, there appears to be a growing recognition that "a science which neglects the reality and distinctive character of large-scale ecological processes provides a poor basis for tackling many of the more urgent problems in natural resources management"

(Edwards *et al.*, 1994).

Like landscape ecology, regional ecology is an interdisciplinary science used to recognize and understand ecological features, processes, and relationships occurring at a broad scale (i.e. the region). While not a formalized field, it is the natural extension of landscape ecology to the study of regions. It lies at the interface of geography and ecology, and like landscape ecology, emphasizes spatial patterns and processes and considers temporal scales in understanding regional processes and change (Forman, 1995). Because regions are comprised of several different landscapes, many of the themes associated with landscape ecology are equally applicable to the study of regions, although they may take on a greater or lesser significance. For example, this includes concepts such as the basic spatial model of patches, corridors, and a surrounding matrix and the interaction amongst these components; natural disturbance and its role in patch dynamics; and metapopulation dynamics, particularly as it relates to k-strategists.

Yet, because regions are more than just a collection of landscapes, regional ecology also incorporates themes not normally associated with landscape ecology. This includes fields in physical geography such as climatology and plate tectonics as well as those in biogeography such as continental patterns of species diversity and patterns and processes of species migration and dispersal. Perhaps the key component here is identifying the point at which a collection of landscapes becomes a region and analysing how broad physical, biological, and human factors have interacted in the past and continue to interact today to make a particular region unique from others.

Similar broad approaches that have recently been articulated include *macroecology*

(Brown, 1995) and *large-scale ecology* (Edwards *et al.*, 1994). As James Brown describes in his book of the same name, macroecology is not a distinct field or discipline but, rather, an approach used to recognize and understand ecological relationships occurring at a broad scale. The macroecological approach emphasizes statistical analysis to quantify patterns of species abundance, distribution, and diversity, thereby addressing Brown's own objectives for broad-scale environmental research (Brown, 1994). Large-scale ecology is a term that emerged from a 1993 meeting of the British Ecological Society (Edwards *et al.*, 1994). Like macroecology it is not a distinct field of ecology but, rather, a distinct approach. It stresses population, species, and community interrelationships and change at large spatial and temporal scales.

Despite their differences, the underlying basis of macroecology, large-scale ecology, and regional ecology is the same: to analyse ecological systems and/or their components at scales much broader than what is traditionally associated with ecological science. They each advocate a more holistic approach to ecology, recognizing that ecological trends or patterns are often indiscernible unless viewed from a broader perspective. In Brown's (1994) own words, "it is hazardous to extrapolate from the results of small-scale experimental studies. Additional processes, neither detected nor important at small scales, often dominate the structure and dynamics of ecological systems at large spatial and long temporal scales" (pg. 22).

2.4.2 Scale and Regional Ecology

Despite its broad application and meaning (see Goodchild and Quattrochi, 1997), the concept of scale is one of the most fundamental aspects of any geographical and ecological research and it is widely recognized that many environmental patterns and processes are scale-dependent (Foody and Curran, 1994). As Pickett and Ostfeld (1995) state:

> "Scaling determines what is internal or external to the system. Whether some event is considered a disturbance or not, what is considered normal variation, what is considered self-regulation, and in fact whether the system is in equilibrium, all depend on the scale at which the system is considered" (pg. 268).

Yet it is the broad nature of regional scales that appears to have hindered a regional approach in ecology[1]. As outlined in Chapter One, Brown (1994) identified the following six challenges that must be overcome in order to facilitate ecological investigations at large (i.e. regional to global) scales:

i. *Developing non-experimental approaches to broaden the scale of ecological research*. It is either impractical or impossible to use a manipulative experimental approach at broad spatial scales. As such, there is a definite need to develop methods for undertaking ecological study at a broad scale that can produce results that offer new and reliable insight into regional ecosystem dynamics.

ii. *Developing new statistical tools.* To conduct ecological research at broad scales in a nonexperimental fashion - yet still be able to test hypotheses - will require new statistical tools and techniques.

iii. *Establishing links with other disciplines*. The traditional unidisciplinary research approach is not well suited in tackling the scale and complexity of regional to global problems. Both a need and opportunity for interdisciplinary research exists,

[1] This stands in stark contrast to geography where, traditionally, regional thinking has been fundamental to the discipline. The difference can be attributed to the greater emphasis placed on a rational, experimental approach by ecologists, as opposed to the more holistic and multidisciplinary approach often utilized by geographers.

and "other disciplines can contribute valuable data and insights" (Brown, 1994).

iv. *Emphasizing synthesis, integration, and modelling.* Scaling up research across disciplines and to broader areas means that researchers must be able to incorporate information from new data sources and other disciplines. Synthesis, integration, and modelling can assist in processing these large quantities of information into meaningful and usable forms.

v. *Standardizing and controlling the quality of data.* A reliance on data collected by other investigators and/or by technological methods increases the need for standards in data collection, management and analysis in order to reduce variations in the quality and precision of data and information used.

vi. *Incorporating humans and their activities*. Humans and their activities must be considered as integral components of ecological systems. This represents a challenge for most ecologists who often view humans as external to the system under study. However, as Brown (1994) states, "it is impossible to disregard the effects of humans on ecological processes at regional to global scales" (pg. 25).

This study addresses the first and fourth of these challenges by emphasizing synthesis and integration of spatial information as a method of broadening the scale of ecological research to gain new insight into the ecological patterns and processes of the greater St. Elias region. A resource survey-based approach using mapping and GIS as fundamental tools in the synthesis and integration of information is utilized. The following subsection provides a background to the development and use of this approach.

2.4.3 Resource Surveys, Mapping and GIS

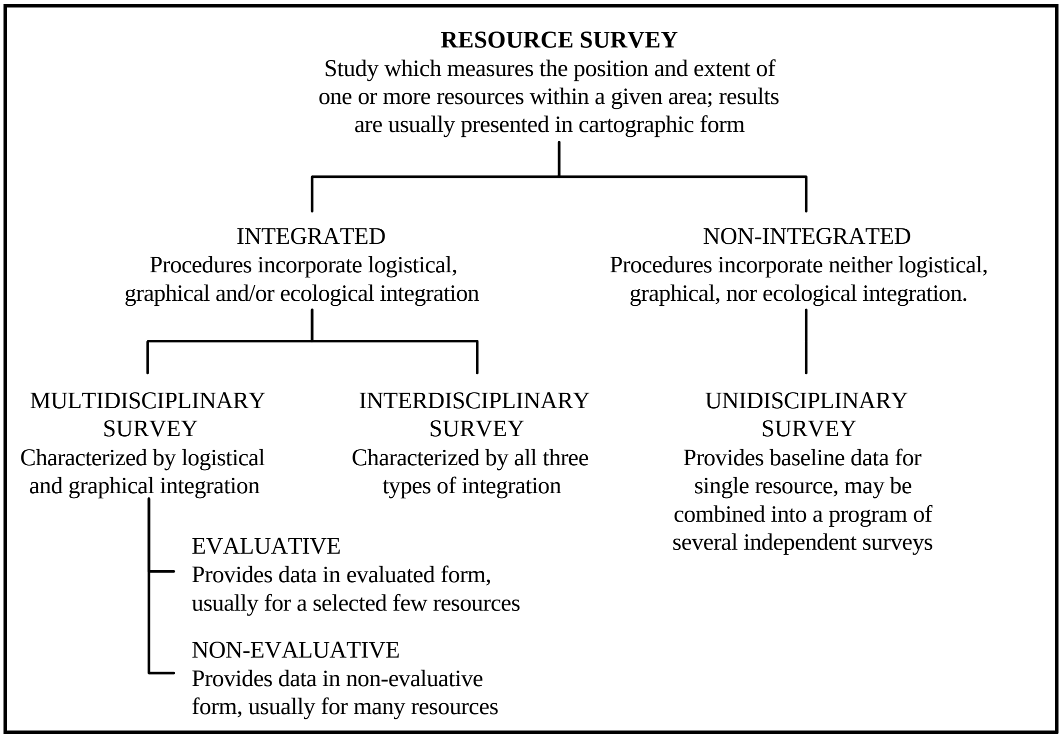
There are a number of approaches and tools that can be utilized in describing and analysing the ecology of regions. There is no "best" approach. Instead, the process, methods, and tools that are used need to be based on the goals and objectives of the project and its intended level of detail. Logistical considerations such as available facilities, budget, and time frame must also be considered. Moreover, the methodology which is utilized must be capable of addressing the key issues and challenges associated with the broad nature of regional scales.

Despite these specific considerations, there are elements that appear to be common to nearly all regional ecological analyses, most notably the integration of spatial information through mapping and - increasingly - geographic information systems by way of a resource survey approach. Simply defined, the resource survey is an approach utilized in "measuring the position and extent of one or more resources within discrete land units" (Bastedo, 1986, pg. 13). Such surveys often follow a predetermined methodology and utilize maps to present results. In an evaluation of resource survey approaches, Bastedo (1986) categorized resource surveys into the schema illustrated in Figure 2.5. The two main categories, integrated and non-integrated, are differentiated by the presence or absence of procedural integration (logistical, graphical, and ecological) during the survey process. Integrated resource surveys are further categorized as being multidisciplinary or interdisciplinary in nature.

Mapping can play an important role in regional ecology by acting as both a tool for data and information synthesis and integration and as a medium for presentation and dissemination of this information. Mapping also plays a critical role in applied resource and environmental management at regional scales; for example, as a tool in parks and protected areas planning and management or in developing and implementing regional

Figure 2.5: Various Types of Resource Surveys

(Redrawn from Bastedo, 1986)



biodiversity conservation strategies (Miller, 1994). Journaux (1987) identifies three fundamental levels of mapping in resource and environmental management:

- *Level 1: Analytical Maps* are generated from the process of mapping simple features or processes. Analytical maps are the most common type used in resource and environmental management.
- *Level II: Systems Maps* are generated from the process of mapping associations of features or processes in order to define systems (physical, biological, or human) or to produce land capability maps.
- *Level III: Synthesis Maps* are generated by combining a wide variety of factors using data processing techniques and/or GIS, or by juxtaposing and superimposing symbols to produce a chronographic map. Synthesis maps integrate physical, biological, and human systems information in order to provide a comprehensive

understanding of an ecosystem and its dynamics and the role or potential role of human activity in these dynamics.

The technological progression of mapping and spatial imaging by way of computers and remote sensing, and the association of data with spatial elements in the form of geographical information systems (GIS), has played a significant role in the development of landscape and regional ecology (Haines-Young *et al.*, 1993). In fact, the past decade has seen a rapid growth in the use of GIS as a tool to aid the design, management, and monitoring of parks and protected areas (Wright and Scott, 1996) as well as in ecosystem management and environmental and resource management in general (Sample, 1994). Heywood *et al.* (1994) denote two main ways in which GIS has been used in these areas: first, "as tools to assist in resource inventory and the integration of data" and, second, "as a mechanism for analysis, modelling, and forecasting to support decision making" (pg. 12). Each of these relate to the first and fourth objectives for regional ecology proposed by Brown, suggesting that the use of mapping and GIS is well suited to this field.

Presented below are three examples of regional ecological synthesis from western North American ecosystems that range in the level of detail at which they were undertaken. Table 2.1 provides a comparison of the three examples. Despite differences in the level of detail at which they were carried out and the process, methods, and tools used, each of the examples had a similar fundamental goal: to integrate widely dispersed information across jurisdictional and disciplinary boundaries to create a regional ecological description analysed to provide potential directions for planning and management.

Table 2.1: Characteristics of the Three Regional Synthesis Case Examples

	Greater Yellowstone	Crown of the Continent	Sierra Nevada	St. Elias (this study)
Relative Detail	Moderate	High	Very High	Moderate
Principle Scale	1:500,000	variable	variable	variable
Organizers/ Authors	US Forest Service & Park Service	Universities, government agencies, NGOs	Government agencies, NGOs, universities, communities	University
Integrative Nature	Multi and Interdisciplinary	Multi and Interdisciplinary	Multidisciplinary	Multi and Interdisciplinary
Method of Integration	Cartography, Summary Data Tables	GIS	GIS, Text	GIS, Text, Data Tables
Method of Dissemination	Report and Atlas	Web-based GIS database	Peer reviewed papers and reports, GIS database	GIS Database, Thesis
Major Biophysical Themes (examples)	Geology, special and unique geological features, groundwater recharge areas, unstable soil and rock. Wildlife habitat (various species), vegetation classification, tree age class	Yet to be confirmed - still in development.	Geological features and processes; fire ecology; taxa status and ecologies; vegetation classification; riparian areas and wetlands; aquatic ecology; past and present climate, species diversity and communities	Physiography (tectonic terranes, neotectonic setting, physiographic regions, relief), climate, hydrology (drainage, glaciers), landcover, large mammal distribution and density
Major Human / Institutional and Resource / Land Use Themes (examples)	Land ownership and administration, management zones, roads and trails, recreation, forestry, mining, rangeland/grazing	Yet to be confirmed - still in development.	Land ownership and admin.; past/present land use; urban development; conservation management; native peoples; recreation; forestry; mining; agriculture and rangelands; socio-economic analysis	Land ownership and administration, parks and protected areas.

2.4.4 Greater Yellowstone Area Aggregation

The Greater Yellowstone Coordinating Committee (GYCC) is an interagency committee comprised of staff from the United States Forest Service (USFS) and the National Park Service (NPS). The committee was initially formed by a 1964 memorandum of understanding (MOU) between these two agencies for the purposes of improving management cooperation between the two national parks and six national forests of the Greater Yellowstone Ecosystem. Support for the committee was reaffirmed by an updated MOU in 1986 that presented 14 goals and objectives (GYCC, 1987).

A year after the revised MOU was signed the GYCC published a report entitled "The Greater Yellowstone Area: An Aggregation of National Park and National Forest Management Plans". The document was prepared "to provide an overview of the management of the Greater Yellowstone Area"(GYCC, 1987) and was designed to illustrate both existing conditions and expected conditions in the future under current management plans and strategies. The aggregation process utilized cartography as a central tool in combining information from the national parks and forests. The final report contained over 50 analytical and systems maps and over 75 illustrative charts and figures.

In many ways the GYCC report acted as a catalyst for raising awareness of the GYE. Since its publication, the concept of a "Greater Yellowstone Ecosystem" has gained widespread acceptance and recognition of the need for regional ecosystem management has grown. The report is, perhaps, most notable for the fact that it was initiated and prepared by both the Forest Service and the Park Service. And while it is primarily descriptive in nature with little analysis of potential future management directions, it illustrate the benefits and advantages that can result from collaborative interagency work.

2.4.5 Crown of the Continent Electronic Data Atlas

The Crown of the Continent ecosystem straddles the Continental Divide in the central Rocky Mountains. The core of the region is centred on the transborder protected area of Waterton Lakes National Park in Alberta and Glacier National Park in Montana. Each of the two parks are Biosphere Reserves and, like the St. Elias Mountain Parks, constitute a joint designation to the World Heritage list. In total, the region is governed by over fifty administrations in BC, Alberta, and Montana (Environment Canada, 1998). With respect to jurisdiction and institutional setting, the Crown of the Continent ecosystem is the most similar to the St. Elias region.

The Crown of the Continent Electronic Data Atlas (CCEDA) is a multi-partner project designed to distribute information on the Crown of the Continent ecosystem to NGOs, the public, industry, governments and academia (Environment Canada, 1998). The CCEDA is an integrated database in the form of a GIS that brings together research across discipline and jurisdictional boundaries through close co-operation with the major data gatherers in the ecosystem, primarily scientists and government agencies. In the words of its developers, the atlas "was formed to overcome limitations to ecosystem management presented by the fragmentation of our knowledge by jurisdiction and subject area" and is intended to provide "a ready view of the 'bigger picture' (that) enhances our ability to determine what research is needed and what is not" (Miikasa Inst., 1998).

Unlike the two other examples described here, the CCEDA is not a fixed product. Because of its electronic nature and open time-frame, information will be continually added to the atlas as new data is made available. Furthermore, while still in the final compilation stage, the CCEDA will soon be accessible via the Internet. This relates to one of the project's fundamental goals which is to create a central data repository readily available to all potential users.

2.4.6 Sierra Nevada Ecosystem Project

The Sierra Nevada Ecosystem Project was a three year congressionally mandated study whose goal was to assemble and assess the environmental data and information necessary to assist in making policy decisions for the future of the Sierra Nevada Mountains of California. A multidisciplinary team comprised of experts from a variety of fields was assembled to carry out the project. The team divided its energy into three periods: (i) data gathering and evaluation, (ii) assessment of the past and current status of the ecosystem, and (iii) projecting and evaluating future trends under varying possible strategies (SNEP, 1996). In the words of its coordinators:

> "The project devoted most of its effort to analysing existing information rather than conducting new studies or experiments. The integration of this accumulated information became a primary objective as the team sought a range of options for future directions of management. The study used geographic information systems extensively as a primary means of synthesizing data, displaying information, and considering options for further analysis" (SNEP, 1996, vol. 1, pg. 2).

The final product of the project was a comprehensive four volume, peer reviewed report and an extensive computer-based catalogue of all public databases, maps, and other digitally stored information used in the project (SNEP, 1996).

The preceding examples from Rocky Mountain ecosystems have been undertaken at a level of detail significantly lower than the Sierra Nevada Ecosystem Project. Furthermore, unlike the other examples, the Sierra Nevada Ecosystem Project considered temporal scale and relations as well as spatial considerations. This not only included historical variation, such as human induced landscape change, but assessment of prehistoric variations as well.

Despite its size and detail, the Sierra Nevada Ecosystem Project appears to have lacked a truly interdisciplinary approach. A multidisciplinary approach was used, and while valuable, there is little in the way of an ecological synthesis to describe how the various ecosystem components interact in the formation of the Sierra Nevada Ecosystem and how the ecosystem functions as a region. Instead, each component or group of components is described and mapped separately; albeit in extensive detail - which at times compensates for the lack of interdisciplinary synthesis.

2.5 SUMMARY

Protected areas are a vital component of any strategy to preserve biodiversity and the integrity of ecosystems. Yet conservation ecology has and continues to demonstrate that most existing parks and protected areas are not capable of preserving native biodiversity and ecological integrity over the long term. On their own, most of these areas are too small to maintain viable wildlife populations or sustain the effects of large natural disturbances. Furthermore, protected areas are often too few or too widely separated to ensure maintenance of regional-scale biological processes such as metapopulation dynamics. Moreover, even the most strictly protected area, no matter what its size, is not immune to negative impacts arising from external sources.

Several strategies have been implemented or proposed in attempts to compensate for these shortcomings. For example, multiple buffer zones like those associated with the biosphere reserve model and multiple use module (MUM) have been advocated and in some cases implemented successfully. Greater park ecosystems have been identified for several protected areas in order to facilitate integrated planning, management, and research at the landscape and regional scale. The maintenance or restoration of linkages between protected areas in the form of habitat corridors has also been encouraged. At an even broader scale, the creation of "reserve networks" and integrated "conservation networks" have been proposed to facilitate conservation across regions.

Often these strategies are placed under the umbrella of ecosystem management; a process that "strives to reconcile the promotion of economic opportunities and livable communities with the conservation of ecological integrity and biodiversity" (Keystone Center, 1996, pg. 6). Yet, ecosystem management entails far more than just "on-the-ground" strategies associated with zoning and land use changes. By most accounts, ecosystem management is about incorporating ecological science into planning and management, institutional change or adjustment, collaborative initiatives, and adaptive approaches to environmental management.

Transborder protected areas offer an additional strategy for countering the innate weaknesses of protected areas. These areas serve to link both protected reserves and nations, providing emergent benefits beyond those associated with their individual components. When used in combination with other strategies such as buffer zones, connective habitat corridors, and ecosystem based management, transborder protected areas can act as valuable anchors in regional conservation strategies. However, because of their international nature and the multiple jurisdictions involved, information on the resources of these areas is often widespread and disjunct, hindering regional ecosystem-based management.

The emerging field of regional ecology can be used to characterize the broad-scale patterns and processes of regional ecosystems and, therefore, act as a foundation for analysis of these systems. Such an approach has traditionally been avoided because of the complexities associated with large spatial scales and the widespread nature of information. Yet the emergence of advanced mapping and spatial data integration technologies, particularly GIS, has made this process more appealing and easier than ever. Recent examples of projects in regional-scale ecosystems like the Greater Yellowstone National Park Ecosystem Area, the Sierra Nevada Mountains of California, and the international Crown of the Continent Ecosystem illustrate the potential of such an approach for facilitating interagency cooperation.

It is hoped that by undertaking a similar project for the St. Elias region, this thesis will further encourage interagency cooperation between the parks and protected areas of the region and will serve to illustrate where such efforts are best focussed. Yet information integration at such a scale is not an easy or straightforward task. The following chapter describes the process which was followed in the production of this thesis and details the methods and tools used to integrate ecological information from across the St. Elias Region.

CHAPTER THREE
PROCESS, METHODS, AND TOOLS

3.1 INTRODUCTION

As detailed in Chapter 2, literature in the field of conservation ecology illustrates that North American parks and protected areas are neither large enough nor numerous enough to sufficiently preserve native biodiversity over the long term. The planning and management of protected areas within their landscape context, combined with implementation of regional-scale ecosystem management can assist in preserving biodiversity as well as protect ecological integrity in existing protected areas. If such strategies are to be implemented - regardless of whether or not they include international frontiers - it is imperative that a picture of the system and how it operates be developed. Despite its relatively recent development, the field of regional ecology appears able to provide a fundamental basis for developing such pictures and, therefore, provides the framework for this study.

In addition to regional ecology, this study borrows heavily from a growing literature in information integration which plays a critical role in the field of regional ecology. Slocombe (in press) defines the meaning of information integration as a process whereby ways are found "to meaningfully link or relate information on different dimensions of an ecosystem to provide a new, fuller understanding of it and especially the connections and relationships between its biological, physical and human dimensions". He also notes that at the heart of this process is the challenge of integrating information about different things, from different sources and in different forms (see Table 3.1). These two observations are quite pertinent to this study which is in many ways an exercise in information integration. The former could be considered the broad, over-all goal of the descriptive portion of this study and the challenges are certainly relevant here. The methodological process and tools described in this chapter were used in this study to assist in overcoming these challenges and to help attain this broader goal.

Table 3.1: Core Issues of Different Kinds of Information Integration

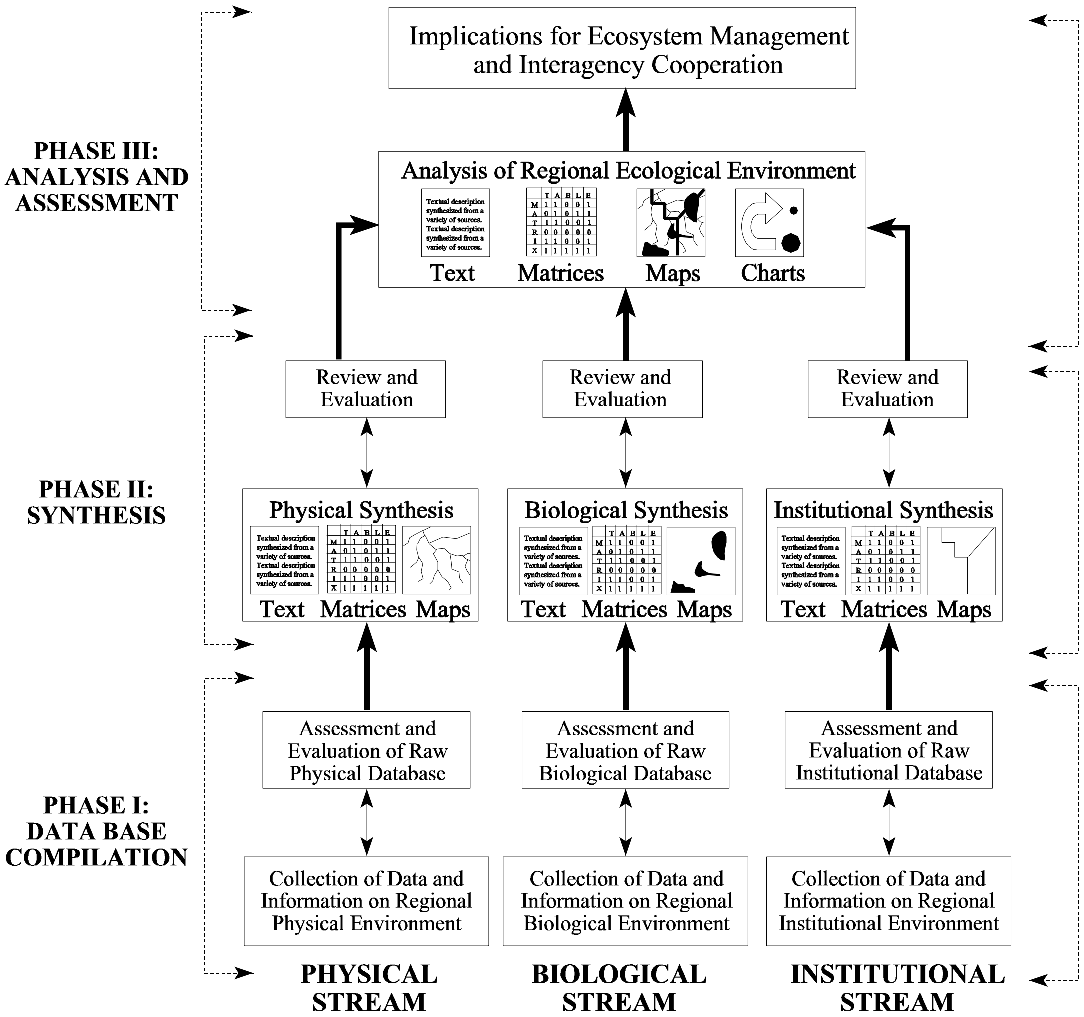
The following table lists many of the issues and challenges associated with integrating ecological information across fields and disciplines (i.e. domains), formats, and sources.
(From Slocombe, in press)

Integration Across Domains	*Integration Across Formats*	*Integration Across Sources*
Identifying points of connection between domains	Different units	Oral - written traditions
Generating new knowledge	Different accuracies and standards	Different views of cause and effect
Certain/uncertain knowledge	Different scales and resolution	Different variable definitions
Predictive or not predictive	Degrees of aggregation	Different system characteristics considered significant
Quantitative/qualitative	Different hardware/software	Information based on experience not experiment or formal study
Spatial and temporal variation	Different digital file formats	Cross-cultural communication
Interdisciplinary communication		
Flexible, accessible products		

3.2 STUDY PROCESS

The methodological process used for this study is presented in Figure 3.1. The general structure of the approach was adapted from the ABC Resource Survey Method, a highly

FIGURE 3.1: PROCESS, METHODS, AND TOOLS



- Generation of systems level maps/charts and summary tables.
- Evaluation of regional character.
- Assessment of implications for ecosystem management of protected areas as well as interagency cooperation.
- Identification of future research needs and evaluation of study process.

- Development of regional GIS via digitizing and data entry using MapInfo.
- Generation of analytical maps
- Dataset combination through data tabulation and matrix creation.
- Assimilation and integration of textual information.

- Interviews with key personel; review and collection of published and unpublished papers, data, reports, maps; regional familiarization
- Review of data and information to identify Phase II components.

adaptable, "hybrid multi/inter disciplinary survey approach" (Bastedo, 1986) which has since been successfully used in a wide variety of circumstances (Bastedo *et al.*, 1984; Nelson *et al.*, 1988; Skibicki, 1995). Like the ABC method the study is divided into a series of "levels" (called "phases" here), which are designed to progressively define significant components of the system under study and, ultimately, provide insight into potential strategies or arrangements for planning and management. In addition, the study is initially divided into three "streams" - each used to describe a particular ecosystem element. While the ABC method labels these streams as abiotic, biotic, and cultural, they are designated here as physical, biological and institutional to better reflect the specific areas of investigation. These three streams are brought together during the third phase of the study and are considered both individually and collectively to assess implications for regional planning and management and interagency cooperation.

Despite these similarities, the process used for this study is also very different from the ABC method. Foremost amongst these differences is the absence of the significance and constraint mapping associated with the ABC method. This is primarily a function of the time, resource, and personnel constraints associated with a master’s thesis. In light of the specific goal and objectives of the study the decision was made to forego this type of mapping in favour of other forms of data and information interpretation and analysis. Additional differences between the ABC method and the methodology used in this study include the presentation of structural and functional ecosystem components on the same maps and the exclusive use of existing inventories rather than primary data collection. A summary of the primary methods and tools utilized in each phase of the study is also presented in Figure 3.1. These phases are described in detail in the following subsections.

3.2.1 Phase Ia - Database Compilation

The first phase of the study consisted of the collection and evaluation of information on the St. Elias region within each of the study streams. Prior to commencement of this phase, a two week reconnaissance trip to Whitehorse and Haines Junction was made in December 1996 to speak with government and park officials as well as residents and regional stakeholders; review previous broad-scale studies undertaken in the region; survey and assess available data and information; and familiarize the researcher with the area in general. During the first half of 1997 an initial literature search was undertaken at several universities in southern Ontario and at the Circumpolar Library at the University of Alberta. Combined with the general literature review being undertaken in conservation ecology and park planning and management, regional-scale conservation, and transborder protected areas (i.e. Chapter 2), this literature search was used to develop the study's goals and objectives.

These initial steps set the groundwork for phase one and the field work portion of the study by facilitating the development of a list of the physical, biological, and institutional themes for which suitable information may be available and, therefore, the types of information and data required from phase one. This included:

- geology, physiography, climate, hydrology;
- major vegetation communities, species diversity, wildlife populations and habitat;
- institutional arrangements for resource and environmental planning and management as well as regional land and resource use.

These themes were intended to be quite broad in nature as the complete extent of available information was not known at the time.

The information collection portion of phase one consisted primarily of an intensive eight week visit to a variety of locations in and near the St. Elias Region during the summer of 1997. This included the Yukon Department of Renewable Resources, the Yukon Public Archives, Natural Resources Canada, Canadian Department of Indian and Northern Affairs, as well as several nongovernmental agencies in Whitehorse; Kluane National Park headquarters in Haines Junction; Tetlin National Wildlife Refuge headquarters in Tok; Wrangell-St. Elias National Park and Preserve headquarters in Copper Center; the US Geological Survey, the University of Alaska, the Alaska Resource Library, the US National Park Service, and the US Fish and Wildlife Service in Anchorage; Glacier Bay National Park and Preserve headquarters in Gustavus; and the US National Forest Service, the Alaska State Library, and the Alaska Department of Fish and Game in Juneau. Offices of the Tatshenshini-Alsek Wilderness Provincial Park in Smithers, BC were not visited. However, telephone conversations with agency staff combined with a week of research in Vancouver at the University of British Columbia did occur.

The process of information and data collection at these various locations consisted of library and database searches combined with interviews with key agency personnel and regional stakeholders. However, it was impossible to predict what types of information would be available from each of the sources. As such, the primary intent here was to collect as much information and gain as much insight and knowledge about each park and its surrounding areas as possible, then evaluate it at a later time within the context of all other information. While this created a certain lack of focus and resulted in research which was - in hindsight - superfluous to the project's objectives, it was nevertheless necessary.

A third trip to the region was made during the summer of 1998. The primary purpose of this trip was to collect additional information and thereby fill any data gaps which had been identified. In addition, the trip facilitated presentation of preliminary research findings to park staff and other stakeholders and thereby receive feedback on map and database accuracy as well as additional data sources. Visitation locales and time frame were approximately the same as the 1997 research trip although time in Juneau and Glacier Bay National Park was foregone in favour of additional time in Anchorage.

3.2.2 Phase Ib - Database Assessment

Assessment of the compiled database constituted the second step of phase one. This was undertaken with two objectives in mind: (i) to define the specific physical, biological, and institutional components which would be examined in the regional biophysical synthesis, and (ii) to survey the state of ecological information on the St. Elias Region and identify disciplines and geographical locales where large gaps exist.

Review and assessment of the compiled database eliminated a number of components from being included in the regional synthesis (i.e. from being carried forward to Phase II). In some of these cases information was sporadic across the region and - given the regional emphasis of the project - aggregation of this information would have yielded less than comprehensive results for interpretive purposes. In other cases, data and information was available for much of the region and was in somewhat compatible formats, but was delimited at a scale that would have required an aggregation effort far beyond the scale of this study.

Human land use provides an illustrative example of a potential study component which was not carried forward to Phase II. While land use information and data is available for much of the St. Elias region, it exists at widely varying scales. Although this information was incorporated into the Regional Institutional Synthesis (Chapter Four), land use mapping is available for only portions of the region. Given that map aggregation was the primary method of synthesis, the lack of detailed land use mapping was seen as a significant hindrance in integrating land use - outside of parks and protected areas and their respective zoning - into the regional GIS as part of this study. However, as will be discussed in the final chapter, the mapping of land use throughout the region appears to be the next logical step in the progression of the GIS database.

Despite the fact that comprehensive land use mapping was not undertaken, some partial land use mapping of the region was undertaken during the initial stages of Phase II as part of an experiment to refine map digitizing techniques and spatial database creation. One theme to be explored was mining, which represents a region wide consumptive resource use activity. Some information on the location of mineral bearing lodes and placer mining claims was logged into the GIS but it was felt that the data was too incomplete to be of further use without more intensive research to obtain additional information. In addition, mapping of land use nodes and corridors using the inverted reserve network model (illustrated in Figure 2.3) was carried out for portions of the region at a scale of 1:250,000. However, for similar reasons, further mapping was not carried out.

Bedrock geology provides a second illustrative example of a potential ecosystem component not carried on to Phase II. The Geological Survey of Canada (GSC) and United States Geological Survey (USGS) have mapped much of the bedrock geology of the region at a scale of 1:250,000. However, individual map sheets contain an innumerable number of polygons and the task of digitizing these map sheets and creating a relational database for the entire region would have been too large for one person to carry out in addition to the other themes considered in this study. As such, it was decided to focus on a broader level of geological classification and utilize bedrock geology mapping and description as a supporting reference.

Ultimately then, the set of ecosystem components that were included in the final regional synthesis (Table 3.2) was a compromise between those which should have been included, and those for which adequate information was available and/or available in a format or scale which facilitated incorporation at the scale of this study.

In addition to those mentioned above, some components - specifically those related to flora and vegetation communities - were cautiously carried forward from this stage. However, as will be discussed in Chapter Five, it was later determined that similar information collected by different agencies was actually incompatible due to very different classification systems and/or data collection methodologies and would have required a synthesis effort beyond the scale of this investigation. Vegetation and ecosystem mapping

Table 3.2: Regional Synthesis - Stream Specific Objectives

Stream	Objectives
Physical	Describe and map: ▸ broad scale geology using tectonic terrains as the basic unit; ▸ neotectonic setting of the region; ▸ physiographic units and relief ; ▸ climatic zones; ▸ hydrology, including major rivers, watersheds, icefields, glaciers, and permanent snowcover. With a view to: ▸ identifying the spatial distribution of broad scale features and processes and the commonalities and differences amongst park units and throughout the region.
Biological	Describe and/or map: ▸ distribution of ecosystems which have been delineated in each of Alaska, Yukon, and BC. ▸ distribution and ecology of umbrella and indicator species (primarily large mammals) Tabulate: ▸ vascular plant, mammal, and bird species lists for each of the protected areas of the region With a view to: ▸ identifying the spatial distribution of species and the commonalities and differences amongst park units throughout the region; ▸ identifying factors responsible for intraregional differences or localized effects.
Institutional	Describe for each protected area and surrounding lands: ▸ history, goals and management objectives ▸ general land use patterns and resource development ▸ current and potential issues Map: ▸ the location, zoning, boundaries, and classes of protected areas in the region ▸ land ownership and administration With a view to: ▸ identifying commonalities in management objectives and the potential for increased interagency cooperation; ▸ identifying regional ecosystem stakeholders.

provides the best example here. As will be discussed in Chapter Five, the combination of considerably different scales, resolutions, and classification systems used in delineating vegetation communities throughout the region precluded spatial integration of this information and imposed a rather descriptive-based aggregation and comparison.

3.2.3 Phase II - Synthesis

Phase Two consisted of the aggregation and integration of information collected in phase one. Three primary techniques were employed here. The first, and most straightforward, was textual synthesis whereby written descriptions from different sources were combined. This was particularly useful in the regional institutional synthesis which required integration of historical, policy, and managerial descriptions from a wide variety of sources. The second major technique employed was the creation of tables and matrices which acted as a useful format for aggregating like information and data as well as summarizing important details.

The third, and most involved, aggregation and integration technique employed in the regional ecological synthesis was creation of a regional GIS database and subsequent map generation. Table 3.3 provides a summary of the map and data layers which were generated. The overall approach utilized here was modelled after Aberley's method for bioregional mapping (Figure 3.2) which emphasizes region-wide properties and trends as opposed to specific local components. A base map was first generated at a scale of 1:250,000 using NTS and USGS topographic grid maps as sources. These maps are used extensively throughout the region and this scale was deemed an appropriate median

Table 3.3: Summary and Status of Regional GIS Map and Data Layers

MULTIPLE SOURCE MAP AND DATA LAYERS (INTEGRATED)			
Theme	**Scale**	**Coverage**	**Details**
Human-Institutional			
Parks and Protected Areas	1:250,000	Entire region	Boundaries and wilderness zones for all designated areas were digitized and clipped to a single map layer with data attached to each polygon.
Land Ownership and Administration	1:250,000	Entire region	Existing digital coverages of land units administered &/or owned by various federal land management agencies; territorial, state and provincial land management agencies; aboriginal-owned lands; Yukon First Nations traditional territories were integrated to create several regional map layers. Pertinent information/data was attached to each polygon.
Major Roads	1:250,000	Entire region	Major roads identified on each relevant 1:250k quadrangle were digitized to a single map layer.
Minor Roads and Trails	1:250,000	Sporadic Coverage	Minor roads and trails identified on some 1:250k quadrangles were digitized to a single map layer but have not been classified.
Settlements	1:250,000	Entire region	Towns and cities from each relevant 1:250k quadrangle were digitized to a single map layer.
Physical Coverages			
Tectonic Terranes	1:2,000,000	Entire region	Fault-bounded tectonic terranes mapped by American and Canadian agencies were digitized to a single map layer with data attached to each polygon.
Earthquake Epicentres	Point data, no scale	Entire region	Location, time, and magnitude data from earthquakes detected by American and Canadian agencies over the past 25 years were integrated into one data layer.
Geothermal Features	Point data, no scale	Entire region	Locations of active and dormant volcanoes, hot springs, and mud volcanoes were plotted onto a single map layer.

Relief	1:1,000,000	Entire region	Hypsography layers from the digital chart of the world were aggregated to one map layer. Elevation data was then attached to each polyline.
Physiographic Regions	1:2,500,000	Entire region	Physiographic regions defined for Alaska, Yukon and BC were digitized to a single map layer. Relevant data was attached to each polygon.
Climate	Point data, no scale	Entire region	Precipitation and temperature data from weather stations in Alaska and Yukon were integrated into one data layer.
Hydrology - Water bodies	1:250,000	Entire region	Rivers, lakes, and marine waters from each relevant 1:250k quadrangle were digitized to respective map layers.
Hydrology - Watersheds	1:250,000	Entire region	Existing digital and digitized analogue sources were integrated to one map layer. Spatial gaps were filled by way of identifying watershed divides through the use of elevation and hydrology layers.
Hydrology - Glaciers	1:250,000	Entire region	Permanent snow and ice identified on each relevant 1:250k quadrangle were digitized to a single map layer.
Biological Coverages			
Dall Sheep Range	<1:250,000	Entire region	Map coverages identifying occupied and historically occupied habitat from Alaska, Kluane NP, Yukon, and BC were digitized into one regional map layer.
Dall Sheep Population Density	Point data, no scale	Sporadic for Region	Population density was extracted or calculated from systematic survey data collected by Wrangell-St. Elias NP&P staff, ADF&G, Kluane NP staff, YDRR staff, and independent researchers, and integrated to create a single regional data layer.
Mountain Goat Range	<1:250,000	Entire region	Map coverages identifying occupied and historically occupied habitat from Alaska, Kluane NP, Yukon, and BC were digitized into one regional map layer. Some existing digital data was integrated into this layer.
Mountain Goat Population Density	Point data, no scale	Sporadic	Population density was extracted or calculated from systematic survey data collected by Wrangell-St. Elias NP&P staff, ADF&G, Kluane NP staff, YDRR staff, and independent researchers, and integrated to create a single regional data layer.

Moose Key Habitat	<1:250,000	Yukon and Alaskan Portions, some BC portions	Map coverages identifying areas of seasonal moose concentration in Alaska, Wrangell-St. Elias NP&P, Kluane NP, Yukon, and BC were digitized into one regional map layer. Existing digital data was integrated into this layer.
Moose Density	Point data, no scale	Sporadic coverage	Population density was extracted or calculated from systematic survey data collected by Wrangell-St. Elias NP&P staff, ADF&G, Kluane NP staff, YDRR staff, and independent researchers, and integrated to create a single regional data layer.
Caribou Herd Distribution and Key Habitat	<1:250,000	Entire region	Map coverages identifying various key habitat and range areas of woodland and barren-ground caribou herds covering portions of Alaska, Wrangell-St. Elias NP&P, and Yukon were digitized into one regional map layer. Existing digital data was integrated into this layer. Pertinent data and information was attached.
Grizzly Bear Key Habitat	<1:500,000	Sporadic across the region	Key habitat, areas of intensive use, known denning sites, and concentrations along fish streams were digitized to a single layer. Pertinent data was attached to each polygon.
Gray Wolf Pack Ranges	1:500,000	Tetlin NWR, Kluane NP and Tat-Alsek	Pack territories identified through surveys conducted by the FWS (1990) and Parks Canada (Skjonsberg, 1996-97) were digitized onto a single layer with pack data attached to each polygon.
Gray Wolf Long Distance Dispersals	Point data, no scale	Kluane National Park and Adjacent areas	Relocation points exceeding 100 km from original capture locations were logged for six collared individuals.

Figure 3.2: Aberley's Method for Bioregional Atlassing

Aberley's (1993) method for identifying and describing bioregions involves the creation of a bioregional atlas through the generation of analytical and systems maps. The process is divided into a series of steps, the first of which is the creation of a base map of the general area under study. This map then acts as the basic layer in the presentation of all other information and facilitates easy comparison between maps. The appeal of Aberley's method is its straightforward approach, logical progression, and adaptability to varying levels of available information.

Create Base Map:

- Choose Features (e.g. coastline, major rivers and water bodies, mountain ranges, major urban centres and roads, etc.)
- Choose Appropriate Scale

Identify and Map:

- Political Boundaries
- Watersheds
- Physiographic Regions
- Major Climatic Divisions
- Ecoregions
- Pre-contact Cultures
- General Land Use
- Additional Biophysical Information as per availability (e.g. vegetation, wildlife distribution, soils, geology, topography and bathymetry, etc.)
- Additional Human Cultural Information as per availability (e.g. sacred sites, historical political boundaries, institutional jurisdictions, etc.)

Define External Boundaries:

- Overlay maps to identify bioregional boundaries

Characterize Bioregion Properties:

- Compile information on physical and biological components of the bioregion such as climatic data, runoff and discharge, wildlife harvest data, etc.
- Compile information on socioeconomic characteristics of the bioregion such as human activities, settlement patterns, resource extraction, pollution sources, economic structure, etc.
- Display spatially in map format with accompanying tables and graphs.

Map Local Areas:

- Identify areas or "nodes" of local bioregional significance (e.g. cities and towns, significant natural areas, etc.)
- Map these areas at a larger scale than previous steps.

between being too fine and too coarse. The base map consisted of marine coastline, international and protected area boundaries, major rivers and lakes, and major highways. This map then acted as the base layer in the presentation of all other physical, biological, and institutional information. The base map is presented in Figure 3.3. Several features, including towns and landscape features mentioned in this text are identified for reference.

All maps were created using a desktop GIS. While there were several factors that contributed to the choice of this medium, the foremost variable was its ease in handling, integrating, and georeferencing source information at varying spatial scales. MapInfo® Professional (versions 4.0 & 4.5) was the software package used. Availability and the researcher's own familiarity with the software contributed to this choice. However, the most influential factor in the choice of MapInfo was its ease of use in manually digitizing maps. This was an important deciding factor as much of the spatial data and information which was collected was in the form of paper maps and required conversion to digital format.

Digitizing accuracy was assessed by using a quadrat sampling methodology whereby several areas of the digitized image were intensively checked against the original map. Corrections were made whenever significant error was encountered. Digital image resolution was assessed using the *minimum mapping unit* (MMU) technique described by Goodchild and Quattrochi (1997), whereby resolution is expressed in linear distance and derived as the square root of "the smallest polygon the cartographer is willing to map". While resolution obviously varied from map to map depending on the source scale, the MMU did not exceed 500 metres for maps generated at a scale of 1:250,000.

FIGURE 3.3 - BASE MAP OF THE ST. ELIAS REGION

(Located In Map Folio)

Spatial information that was already in digital form was most often in ArcExport format (.e00) and was converted to MapInfo format using ArcLink®. Because of its limited data handling properties MapInfo is often not considered a "true" GIS platform. However, the data query and analysis capabilities of a comprehensive GIS package such as ESRI's ArcInfo® were not required for this study. Nevertheless, MapInfo files can be converted for use in ESRI' s ArcView and ArcInfo as well as other popular GIS platforms. Given the potential use of the integrated database in the future by additional parties, this was another key variable in the choice of MapInfo.

Specific methods and sources used in creating each data layer were logged into a metadata catalogue which also includes details on map projection and coordinate systems, scale and resolution, data structure and fields, notes on variations amongst source information, and degree of edge matching required amongst sources.

3.2.4 Phase III - Analysis and Assessment

As conceptualized in Figure 3.1, the final phase of this study was undertaken in two stages. The first of these, analysis of the regional ecological environment, was undertaken with a view to assessing the relative degree to which the St. Elias Mountain Parks function as a coherent ecological unit. In carrying out this stage, particular attention was paid to identifying and characterizing the relative degree of connectivity between areas. This included the identification of potential metapopulation structures, transboundary wildlife movements, significant transboundary habitat, wildlife movement corridors, and description of the general biogeographic character of the region. Emphasis here was placed on the interplay between the physical and biological environment of the region. The institutional and biophysical syntheses acted as the foundation for this phase by providing the fundamental information - both spatial and numeric - that was required for analysis.

Systems maps were generated during this stage to identify regional linkages and properties. However, as the reader will observe in Chapter Six, these maps were created at a broader scale than those in Phase II so as to indicate the interpretive and/or conceptual nature of the results (as opposed to the largely analytical maps generated in Phase II). These maps were created with a desktop graphics program (Corel Draw) utilizing a 1:2,500,000 scale base map which had originally been generated in MapInfo. The graphics program was utilized as it was better suited to illustrating trends and systems at this broader scale.

The second stage of Phase III was undertaken with a view to identifying the implications of the synthesis and analysis for coordinating interagency cooperation within a regional ecosystem management framework. As discussed in Chapter Two, several authors have defined criteria, goals, and/or objectives for ecosystem management. Grumbine (1994) reviewed these and identified the five most common:

1. Maintain viable populations of all native species in situ;
2. Represent, within protected areas, all native ecosystem types across their natural range of variation;
3. Maintain evolutionary and ecological processes;
4. Manage over periods of time long enough to maintain the evolutionary potential of species and ecosystems;

5. Accommodate human use and occupancy within these constraints.

These five goals were used as guidelines in assessing the implications of the regional biophysical synthesis and ecological analysis. The approach used here was to identify general implications and broad management goals for the entire region and then to identify more specific management objectives related to the region's parks and protected areas, particularly those related to integrating management of the core areas with surrounding less protected and unprotected areas and coordinating cooperation between management agencies.

3.3 SUMMARY

As outlined in this chapter, this thesis can be conceptualized as occurring in three separate "phases": Database Compilation, Synthesis, and Analysis and Assessment. In reality however, these phases were not carried out independent of each other. Similarly, while each phase was conceptualized as comprising two or three "steps" or "stages" with independent objectives, these stages were often undertaken simultaneously. In the end, however, each phase generated a definite "product" - tangible or not. The product of Phase I (Database Compilation) exists in the volume of information gathered by the author in the form of reports, data sheets, published papers, management plans, maps, atlases, and personal interviews. Many of these references are logged in the Metadata presented in Appendix C or in the Literature Cited section at the end of this thesis. The products of Phase II (Synthesis) are presented in the following two chapters while the products of Phase III (Analysis and Assessment) are presented in Chapters Six and Seven.

CHAPTER FOUR
REGIONAL INSTITUTIONAL SYNTHESIS

4.1 INTRODUCTION

The St. Elias Region comprises a core of three national parks and one provincial park surrounded by an array of public lands offering varying levels of protection. Figure 4.1 illustrates the spatial configuration of protected areas in the region and Table 4.1 provides data and information related to the map. From the map, it is apparent that the regional pattern of land status is similar to that of the Biosphere Reserve model described in Chapter 2. Although it lacks the outer third zone, the four national parks and equivalent reserves act as the protected core of the region, while surrounding wildlife preserves, sanctuaries, and national forests could be considered analogous to a buffer zone. The Figure also illustrates areas zoned as wilderness within the parks and protected areas. These areas provide the highest level of protection in the region.

This chapter details the institutional setting of the St. Elias Region by summarizing management objectives and land use patterns associated with each protected area. Related institutional arrangements and general land use for surrounding lands are also summarized. The reader is referred to Appendix B for a detailed history and description of the institutional environment associated with each protected area described here. The chapter concludes with an analysis of existing interjurisdictional linkages and cooperation throughout the region. Given the dominant nature of publicly owned land in the St. Elias region, and the north in general (see Nelson *et al.*, 1987, for reviews), federal and

FIGURE 4.1: PARKS AND PROTECTED AREAS OF THE ST. ELIAS REGION

(Located In Map Folio)

Table 4.1: Parks and Protected Areas of the St. Elias Region

Park/Protected Area	Management Agency	km²*	IUCN Class	Year Est. and Designation
Kluane National Park and Reserve	Canadian Department of Heritage - Parks Canada	22,013	II	1943- Game Sanctuary 1976- National Park Reserve 1994- National Park & Reserve
Wrangell-St. Elias National Park & Preserve ▸ ***(National Park)*** ▸ ***(National Preserve)***	USDI National Park Service	53,420 *(32,765)* *(19,655)*	II&V *(II)* *(V)*	1978 - National Monument 1980 - National Park and Preserve
Glacier Bay National Park & Preserve ▸ ***(National Park)*** ▸ ***(National Preserve)***	USDI National Park Service	13,287 *(13,053)* *(234)*	II&V *(II)* *(V)*	1925 - National Monument 1980 - National Park and Preserve
Tatshenshini-Alsek Wilderness Provincial Park	BC Ministry of Environment, Lands and Parks - BC Parks	9,580	II	1993 - Provincial Class "A" Park
Tetlin National Wildlife Refuge	USDI Fish and Wildlife Service	3,739	IV	1980 - National Wildlife Refuge
Kluane Wildlife Sanctuary	Yukon Department of Renewable Resources	6,368	IV	1943 - Game Sanctuary
Chilkat River Eagle Preserve	Alaska Dept. of Fish and Game (ADF&G)	199	II	1982 - State Critical habitat Area
Chugach National Forest	USDA Forest Service	27,959	VI	1907 - National Forest
Tongass National Forest ▸ ***(Russell Fiord Wilderness)*** ▸ ***(Endicott River Wilderness)***	USDA Forest Service	70,606 *(1,411)* *(400)*	VI *(I)* *(I)*	1902 - Forest Reserve 1907 - National Forest

* "Official" areas obtained from respective management agencies

state/provincial/territorial government agencies are the primary focus of discussion in this chapter. First Nations are increasingly gaining recognition as a form of government - particularly in Yukon - and are also discussed. However, while their role is recognized, other stakeholders in the region such as nongovernmental organizations (NGOs) and local or municipal governments play a smaller role and are not examined in detail at this scale.

4.2 NATIONAL PARKS AND EQUIVALENT RESERVES

Kluane National Park and Reserve, Tatshenshini-Alsek Wilderness Provincial Park, Glacier Bay National Park and Preserve, and Wrangell-St. Elias National Park and Preserve serve as the protected core of the St. Elias Region. Despite their continuous nature, specific land designations in each of the four areas are very different, and zoning within the two American parks is quite complex.

Approximately one half of Kluane National Park remains under reserve status - a designation granted to an area where native land claims have yet to be settled. In 1994 the Champagne-Aishihik First Nation settled their land claim in the southwestern portion of the Yukon and a portion of Kluane was released from reserve status (Seale, 1996). The remainder of Kluane is expected to be released from reserve status in the near future as the Kluane First Nation have just completed negotiations on their respective land claim which covers the northern portion of Kluane National Park and Reserve. Most of Kluane is zoned as wilderness where only those activities requiring limited primitive facilities are allowed. A similar approach to zoning is taken in the Tatshenshini-Alsek Park. With the exception of the Haines Highway corridor, the entire park is zoned for wilderness preservation (WCMC, 1997).

Wrangell-St. Elias and Glacier Bay comprise two broad designations: national park, where sport hunting is not permitted; and national preserve, where it is permitted. Superimposed upon this dual land designation is congressionally legislated Wilderness where, amongst other things, motorized vehicle access is not permitted. This results in four general land classes in Wrangell-St. Elias: national park, national park wilderness, national preserve, national preserve wilderness. These same classes are observed in Glacier Bay with the added levels of wilderness waters and nonwilderness waters within the National Park.

Land use in each of the four core protected areas is broadly similar in that much of it is centred on activities traditionally associated with parks and protected areas. This generally includes recreational activities such as hiking, backpacking, mountaineering, and fishing in each of the four parks. More intensive activities in each of the parks include rafting on the Tatshenshini and Alsek Rivers and vehicle sightseeing with associated day-hiking along the Haines Road corridor in the Tatshenshini-Alsek Wilderness Provincial Park. Boating on Glacier Bay and kayaking along the Glacier Bay coastline is the predominant form of recreation in Glacier Bay National Park and Preserve. Vehicle sightseeing with associated day-hiking is predominant in Kluane National Park by way of the Haines Road and Alaska Highway corridor along the Park's eastern periphery as it is in Wrangell-St. Elias National Park and Preserve along the Glennallen Highway, Nabesna Road, and McCarthy Road corridors. In short, virtually all visitor use in each of the four areas is concentrated along one or two linear areas.

Subsistence harvest is permitted in each of the four areas. However, the extent and definition of what constitutes subsistence use varies between them. First Nations have the legal right to all types of subsistence harvest in Canadian National Parks. With the exception of a special "no-harvest zone" negotiated during their land claim agreement, the Champagne and Aishihik have subsistence rights in their traditional territories located within the park and the Kluane First Nations have subsistence rights in areas which remain a national park reserve.

Aboriginal people also have a legal right to use provincial parks in British Columbia for traditional sustenance activities. In the Tatshenshini-Alsek Wilderness Park this use is undertaken mainly by the Champagne and Aishihik First Nations whose traditional territory extends into this area. Table 4.2 provides a breakdown of this subsistence use as well as consumptive use in all other parks and protected areas discussed here.

The rules governing subsistence use in the Alaskan parks are slightly more complex. One of the purposes for which Wrangell-St. Elias was established was to allow for continuation of subsistence lifestyles (Table 4.3). To this end, traditional resource use by local residents - not just First Nations - is permitted throughout the park and preserve. To be considered a local resident, and therefore be entitled to subsistence use of national park lands, an individual must have their primary address in an area that has been identified by park management as a local community. Methods by which subsistence use is carried out is also regulated (FSB, 1997) and a recent study by Haynes and Walker (1995) has assisted in identifying traditional access routes and methods of subsistence use in the area.

Table 4.2: Purpose, Management Objectives, and Current Management Issues & Foci

Park	Purpose of Establishment	Primary Mgmt. Objectives	Issues &/or Management Foci (examples in no particular order)
Kluane NP	"To protect for all time, and to present to the public, a natural area of Canadian significance representative of the Northern Coast Mountains Natural Region"	"To preserve the wilderness character of Kluane National Park Reserve."	▸ Increasing backcountry use ▸ Increasing frontcountry use and visitation ▸ Native land claim settlements ▸ Local participation in resources management ▸ Territorial wolf kill ▸ Spruce bark beetle infestation ▸ Development along park periphery
Wrangell-St. Elias	To maintain scenic beauty of the landscapes in their natural state; To protect wildlife habitat; To provide opportunities for wilderness recreational activities; To provide an opportunity for traditional subsistence use.	"To manage the park in such a manner that the purposes for which the park was established remain unimpaired."	▸ Increasing backcountry use ▸ Increasing frontcountry use and visitation ▸ Hunting limits ▸ Defining "customary and traditional" use ▸ Spruce bark beetle infestation ▸ ATV impacts ▸ Land use on inholdings
Glacier Bay	To protect tidewater glaciers, surrounding mountain peaks and forests, and provide "opportunity for scientific study of glacial behaviour and of resulting movements and developments of flora and fauna"	To manage the park and its use as to conserve the area and "its continuing natural succession processes in a natural condition".	▸ Commercial fishing ▸ Marine vessel access and use ▸ Increasing backcountry use and visitation ▸ Spruce bark beetle infestation ▸ Outreach to native peoples
Tatshenshini-Alsek	To protect "for future generations" an area "representative of the best natural features and diverse wilderness environment of the province".	To conserve natural diversity, wilderness quality, and cultural values and provide compatible recreation activities	▸ Increasing backcountry use ▸ Spruce bark beetle infestation ▸ Continued mining lobbying ▸ Impacts from rafting expeditions ▸ Sport hunting

Table 4.3: Consumptive Resource Use in the St. Elias Protected Areas

Activity	Kluane	Wrangell	Glacier Bay	Tat-Alsek
Sport Fishing	Yes	Yes	Yes	Yes
Commercial Fishing	No	No	Yes	No
Subsistence Hunting	Limited to Local First Nations.	Local residents by customary and traditional means.	In National Preserve only.	Limited to first nations.
Sport Hunting	No	In National Preserve only, in accordance with park specific regulations.	In National Preserve only, in accordance with park specific regulations.	Yes, in accordance with provincial hunting regulations.
Subsistence Forestry/ Wood Harvest	In support of subsistence hunting.	Firewood cutting by park residents only. Greenwood harvest can occur only to support subsistence hunting.	Preapproved harvest of hazard trees by local residents for firewood only.	In support of subsistence hunting.
Commercial Forestry	No	On private inholdings only	No	No
Mining	No	Permitted on private inholdings, >700 valid claims.	One set of valid claims.	No

Activity	Tetlin	Kluane WS	Tongass	Chugach
Sport Fishing	Yes	Yes	Yes	Yes
Commercial Fishing	Permitted on private inholdings, potentially on refuge land	Yes	Yes	Yes
Subsistence Hunting	Yes	Yes	Yes	Yes
Sport Hunting	Yes	No	Yes	Yes
Subsistence Forestry/ Wood Harvest	Yes	Yes	Yes	Yes
Commercial Forestry	Permitted on private inholdings, potentially on refuge land	Yes	Yes	Yes
Mining	Permitted on private inholdings, potentially on refuge land	Yes	Yes	Yes

With the exception of fishing, subsistence use of Glacier Bay is limited to the National Preserve. In fact, fishing of all types - including commercial fishing - continues on Glacier Bay despite the fact that it has been ruled illegal in all US National Parks.

4.3 NATIONAL FORESTS AND WILDLIFE PRESERVES

The Tetlin National Wildlife Refuge, Kluane Wildlife Sanctuary, Chilkat Bald Eagle Preserve, and Chugach and Tongass National Forests are the five major areas adjacent to the four core protected areas that provide moderate levels of natural heritage protection. While they are discussed together here, they are actually quite different and are described separately in detail in Appendix B.

Tetlin National Wildlife Refuge provides the most protection of these areas. It was established under the Alaska National Interest Lands Conservation Act (ANILCA) in 1980 for a variety of purposes, mostly relating to the conservation of fish and wildlife populations and habitats and to provide for subsistence use of these resources. Hunting is permitted within the refuge and mining in a legitimately claimed area is also permitted. Commercial logging is typically not allowed but may be carried out in conjunction with management purposes. Habitat management for specific species groups - particularly waterfowl and ungulates - is practised extensively throughout the Refuge, primarily through prescribed burns to encourage new growth.

The Kluane Wildlife Sanctuary is administered by both the federal and territorial governments. Like other wildlife sanctuaries in the Yukon, the land and timber resources are federally owned and administered, yet wildlife resources are managed by the Yukon

Department of Renewable Resources. The only restriction on resource use within the sanctuary is a territorially assigned prohibition of "hunting, trapping, killing, shooting at, wounding, injuring, or molesting any game" (Theberge, 1978). Apart from this, the area is open to any activity that would permissibly occur on any other Territorial land. Designation of a portion of the northern sanctuary surrounding the Klutlan Glacier as a Territorial Park will be a likely outcome of the land claim negotiations occurring between the Yukon Government and the Kluane and White River First Nations (Peepre, pers. comm., 1997; West, pers. comm., 1998).

The Chilkat River State Critical Habitat Area, commonly known as the Chilkat Bald Eagle Preserve, protects habitat for the world's largest concentration of Bald Eagles *(Haliaeetus leucocephalus)*. The Chilkat River supports late salmon runs which attract thousands of eagles from across southeast and south-central Alaska. Despite its size it serves an important ecological role at both the local and regional scale. Land use in the area is managed for the purposes of protecting bald eagle populations and their habitats, protecting salmon spawning and rearing areas, protecting riparian ecosystems, protecting populations of other bird and mammal species, and providing opportunities for scientific study and research (ADNR, 1985).

The Tongass and Chugach National Forests are managed under the canons of multiple use and sustained yield (Tuchmann *et al.*, 1996, pg. 13). Each forest is a patchwork of land designations where permitted land use ranges from intensive logging and resource extraction to legislated Wilderness areas where all resource extraction and motorized access is prohibited. Key here to the protected areas of the St. Elias region are the Russell Fiord Wilderness and Endicott River Wilderness areas.

4.4 ADJACENT LANDS

Lands adjacent to the protected areas of the St. Elias fall into three broad categories of ownership: private, public, and tribal or native lands. As illustrated in Figure 4.2, the majority of these lands are publicly owned and are administered by either State, Provincial, Territorial, or Federal agencies. Figure 4.2 also illustrates differences in the patterns of ownership and administration of public lands between Yukon, Alaska, and British Columbia and these are discussed below.

Most public lands in the Yukon are federally owned and are administered by the Canadian Department of Indian and Northern Affairs (DIANA). Natural Resources such as water, forests, and minerals are also managed by federal agencies. The one major exception to this is fish and wildlife, which are managed by the Yukon Territorial Government's Department of Renewable Resources.

As a Canadian Province, most public lands in British Columbia are provincially owned and administered. There is little federal land in the vicinity of the St. Elias region in British Columbia, and several provincial agencies are responsible for the management of unprotected lands and natural resources in the region. This includes the BC Ministry of Environment, Lands, and Parks (BC MELP) and the BC Ministry of Forests (MOF).

Alaska represents the median between the public land ownership extremes of Yukon and British Columbia, having a mix of both federal and state lands. However, this also complicates land administration in the state by creating a veritable patchwork of

FIGURE 4.2: LAND OWNERSHIP AND ADMINISTRATION

(Located In Map Folio)

jurisdiction and administrative agencies. As a result of ANILCA in 1980, a large portion of Federal lands were conveyed to State authority. Additional lands remain under Federal ownership but have been selected by the state for future conveyances.

Local municipal governments have relatively small landholdings and virtually no role in resources management in either Yukon, Alaskan, or British Columbian portions of the region. These are the unmarked areas on the map of Figure 4.2.

Lands held by aboriginal peoples comprise the second category of land outside of protected areas in the St. Elias region and the conveyance of land to aboriginal groups has followed very different routes in the Alaska, British Columbia and the Yukon. In Alaska aboriginal claims were settled in 1973 through the Alaska Native Claims Settlement Act (ANCSA) before most of the region's protected areas were established by ANILCA. ANCSA created regional native corporations and provided cash and land settlements to be administered by these corporations (see Naske and Slotnick 1987, for general background). Some corporations were then subdivided into village corporations while others remained solely as regional corporations. The regional corporations occupying portions of the St. Elias include Ahtna Inc., Doyon Ltd., Chugach Natives Inc., and SeaAlaska Corp.

Three Yukon aboriginal groups have traditional territory in the greater St. Elias region; the Champagne and Aishihik, Kluane, and White River First Nations. Following extensive and difficult negotiations throughout the 1980s an Umbrella Final Agreement (UFA) for the Yukon comprehensive claim was signed in 1990. Local, band-specific agreements have been and continue to be negotiated from that. The Champagne and

Aishihik signed their Final Agreement in 1993, the White River First Nation signed their Final Agreement in 1998, and the Kluane First Nation's Final Agreement is awaiting ratification by the band council. Each of these agreements has and will convert land ownership to the first nation groups as well as ensure their direct involvement in all resource management activities within their traditional territories.

Settlement of claims has only recently begun in British Columbia, and really not at all in the extreme northwest of the province. As such, while the traditional territory of the Champagne and Aishihik First Nation includes the portions of the St. Elias Region that extends into British Columbia, their land holdings within the province are, for discussion purposes here, insignificant.

Privately owned lands make up the final category of lands adjacent to the protected areas of the St. Elias region. Land status in this category may range from residential lots to university-owned lands to lands owned by industry. Compared to the total extent of public and native-owned lands, private lands are rather small. However, the number of individual parcels of privately owned land is relatively large in comparison, and therefore necessitates the inclusion of private land owners in any regional-scale approaches to management.

4.5 COOPERATION

As Gray (1992) noted, collaboration in managing natural resources has a long history in the St. Elias Region, beginning with cooperation between the native peoples of the Interior and the Coast. European settlement of the area required cooperation between

Russian, French, Spanish, British, and American fur traders, and the governments of these countries were involved in a series of negotiations leading to allocation of the region's fur resources. American purchase of Alaska in 1867 ushered in a new era in regional cooperation as the US and Canada negotiated international boundaries. The discovery of gold in Alaska and the Yukon and the subsequent migration of peoples from the south further necessitated cooperation between these two nations (Gray, 1992).

The process of collaboration is significantly more complex today though. As was illustrated in Figure 4.2, in addition to the two nations and their respective agencies, a US state, Canadian territory, Canadian province, and several first nations and local governments also govern the region. Figure 4.3 summarizes the major cooperative relationships among these agencies as they relate to protected area management. As illustrated in the Figure, cooperation between these agencies ranges from simple informal relationships to complex formal agreements. Formality is based on the relative importance placed on written agreements such as legislation, international agreements, MOUs, etc., in assuring the maintenance of, and commitment to, the relationship. Complexity is based on a combination of factors, primarily the number of agencies involved, the intricacy of the cooperative arrangement, and the relative effort it takes to maintain the agreement or relationship.

Figure 4.3 appears to illustrate a definite relationship between the complexity and formality of intergovernmental cooperation in the St. Elias region. Generally, complex intergovernmental cooperation is accompanied by formal agreements. A second relationship which is not directly evident through the figure, but is inferred through the

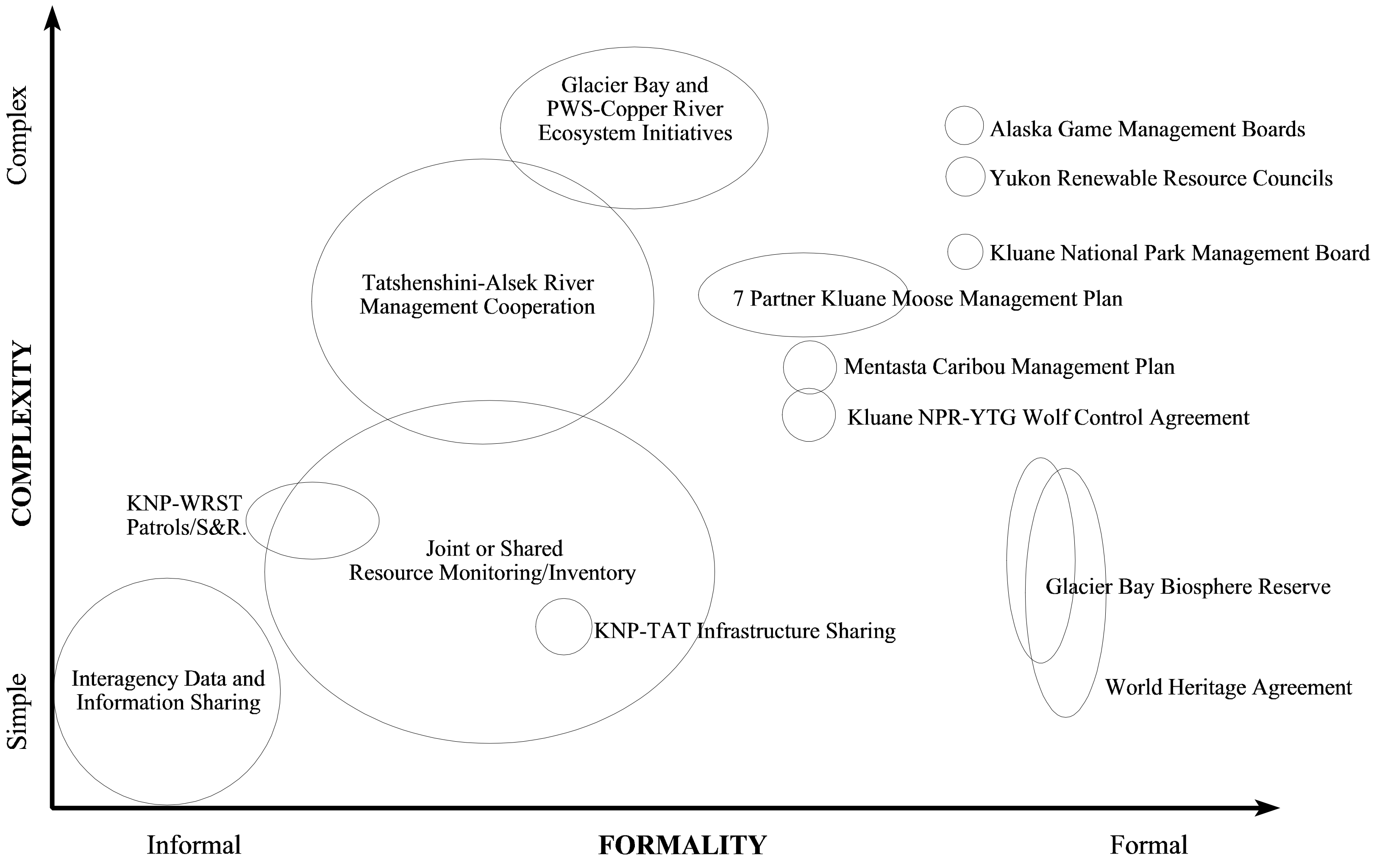


Figure 4.3: Primary Examples of Interagency Cooperation in the St. Elias Region

Table 4.4 (supplement to Figure 4.3)
Primary Examples of Intergovernmental Cooperation

Communication and Information Sharing is the most extensive type of intergovernmental cooperation to occur in the St. Elias region. Common examples include exchange of publications, data, and information between agencies as well as telephone conversations, correspondence, and informal meetings among peers.

Examples of ***Joint or Shared Resource Monitoring/Inventory*** are numerous and include joint and shared fish and wildlife monitoring by federal protected area management agencies (i.e. Parks Canada, US NPS, and US FWS) with state/territorial fish and wildlife departments (i.e. YDRR and ADF&G); joint water quality analysis and snow survey plots by DIAND and Parks Canada; shared spruce beetle and forest fire monitoring and research projects in Yukon between Parks Canada and DIAND and in Alaska between ADNR, USFS, and US NPS; and marine resource monitoring shared between Wrangell-St. Elias and Glacier Bay National Parks.

While much less extensive today than in the past, Kluane and Wrangell St. Elias National Parks occasional undertake ***Joint Patrols and Search and Rescues***. Meetings between Kluane Wardens and Wrangell-St. Elias Rangers regarding remote boundary issues such as poaching, mountaineering, and border crossing have also occurred.

Multiagency cooperation in ***Tatshenshini-Alsek River Management*** has received significant attention, particularly since the Windy-Craggy mine proposal. Since establishment of the provincial park and prevention of mining in the area, efforts have focussed on cooperating on management of river-based recreation such as rafting.

Parks Canada and BC Parks have an ***Agreement on Infrastructure Sharing*** whereby Kluane National Park provides office space, equipment, and personnel support for Tatshenshini-Alsek PP rangers and staff. Parks Canada also provides assistance with wildlife surveys and other resource inventory activities.

The ***Glacier Bay / PWS-Copper River Ecosystem Initiatives*** are administered by the USGS Biological Resources Division (BRD) to “promote an ecosystem perspective for the use and management of natural and cultural resources, land, and water in the region” (Oakley, 1997). The initiatives have been formally adopted through multiagency memorandums of understanding (MOU). Collaborative projects such as GIS databases, resource bibliographies, and public outreach have been used to assist in information dissemination and education, and meetings between representatives of the various land administration agencies occur regularly (Geisleman, 1997; Oakley, 1997).

The Aishihik Wolf Control Agreement is a formal agreement between Parks Canada and the Yukon Territorial Government. Wolves that were known to spend 50% of their time within Kluane National Park or den in Kluane National Park were not to be killed in the wolf control program that took place from 1993 to 1997. In addition, a no-kill zone was established around the perimeter of the National Park. Collaborative monitoring by Parks Canada and YTG staff was undertaken to assess the residency status of wolves.

The Mentasta Caribou Management Plan is a formal plan developed by the US National Park Service, US Fish and Wildlife Service, and Alaska Department of Fish and Game to cooperatively manage the declining Mentasta woodland caribou herd.

The southwest Yukon ***Multi-Agency Moose Management Board*** is a multi-partner agreement between Kluane NP, Tatshenshini-Alsek PP, Yukon DRR, Champagne and Aishihik First Nation, BC MELP, and the Alsek Renewable Resources Council (RRC) established for the purpose of cooperatively managing moose harvest in the southwest Yukon and northwest British Columbia. It has a greater range of formality than the previous two examples because not all parties have signed the formal agreement.

Kluane, Wrangell-St. Elias, Glacier Bay, and the Tatshenshini-Alsek Wilderness are each part of the St. Elias Mountain Parks ***World Heritage Site*** and Glacier Bay and Admiralty Island to the south are designated as a ***Biosphere Reserve***. Each of these international designations are granted by UNESCO but do not change the site's jurisdictional status. Although such designations are given a higher status in other parts of the world, they are largely symbolic in the St. Elias region and have little influence on the specifics associated with planning and managing the protected areas.

The ***Kluane National Park Management Board*** and ***Alsek Renewable Resources Council*** were established after settlement of the Champagne and Aishihik First Nations land claim. They are formal boards that facilitate the First Nations' negotiated right to active participation in natural resource planning and management. The Kluane First Nation will be involved in a similar fashion following settlement of their land claim.

listed examples, is the fact that cooperation is significantly less frequent between agencies on opposite sides of the international border. These two trends are discussed further in Chapter 7 in the context of the regional ecological synthesis.

For purposes of discussion, the cooperative relationships illustrated in Figure 4.3 can be grouped into five general categories based on common characteristics: communication, coordination and collaboration, cooperative management, joint management, and international agreements. Each of these categories along with typical examples from the St. Elias region are described in the following sections.

4.5.1 Communication

General communication and information sharing between agencies sharing a particular resource is the most common type of management cooperation. Furthermore, by acting as a foundation for more complex and/or formal cooperation it is also the most extensive. Communication varies from simple telephone conversations between peers in different agencies to more formal meetings involving several different agencies. For the most part however, it is rather simple and informal in nature.

Wildlife data and information sharing is the most common form of intergovernmental cooperation in the St. Elias. Most often this occurs in the form of telephone conversations and correspondence between government biologists. Such communication occurs freely across jurisdictional boundaries and among administrative agencies - particularly between federal protected areas and state/ provincial/ territorial agencies. For example, Parks Canada wardens undertake regular surveys of large mammals in Kluane National Park. Results of these surveys are passed on to the Fish and Game Branch of the Yukon Department of Renewable Resources (DRR) and individual staff of these branches sometimes meet to discuss wildlife population trends. Similar relationships exist between resources management staff at Glacier Bay and Wrangell-St. Elias National Parks and biologists at the Alaska Department of Fish and Game (ADF&G).

Although this analysis is focussed on intergovernmental cooperation, communication is also the level of cooperation which most involves actors and regional stakeholders beyond the level of government. This includes environmental nongovernmental organizations such as the Canadian Parks and Wilderness Society, the Wilderness Society, the Sierra Club, as well as private landowners, residents, and resource users and user groups such as the Yukon Chamber of Mines. Other forms of communication such as interpretive programs and public outreach also fall under this category.

4.5.2 Coordination and Collaboration

Coordination and collaboration represents the next level in management cooperation in the St. Elias region. This is an extensive category that is comprised of a wide variety of cooperative relationships like activity coordination, joint programs, collaborative research and monitoring, infrastructure and resource sharing, and soliciting input from a neighbouring agency on a specific management issue. The rationale for such cooperation is also wide ranging. The existence of transboundary resources or shared management issues may be a factor, or coordination and collaboration may be necessitated because of expertise in one organization not shared by another. The benefits associated with economies of scale and reduced duplication of tasks may also initiate these relationships. In any case, the cooperation between agencies is almost always viewed as being equally beneficial to all parties involved.

For the most part, activity coordination and collaborative initiatives are not directed by highly formal agreements. MOUs are often used but such agreements are not binding and do not require a substantial level of effort to maintain desired results. On the other hand, these cooperative relationships are not nearly as simple and informal as interagency communication. This is the level at which most of the interpark cooperation in the St. Elias Region occurs.

A good example of interagency coordination and collaboration is the recent focus on management of the Alsek watershed. Given the rise in use of the Tatshenshini and Alsek Rivers in recent years, current efforts have focussed on regulating river-based recreation to avoid ecological impacts and maximize visitors' wilderness experience. While the potential for an international management plan has been discussed, formal dialogue has yet to be initiated. Instead, Glacier Bay's "Alsek River Visitor Use Management Plan" (NPS, 1989) - which was developed with consultative input from Kluane National Park, Tongass National Forest, and the BC Government, as well as river users - has served as a framework for developing visitor use regulations for the entire river system. There are now common permit requirements, similar limits to group size, and common camping and access restrictions throughout all protected portions of the river system. Moreover, while the regulations are not enforceable on the unprotected portions of the river system, commercial operators have agreed to adhere to the park regulations outside of the parks. These regulations and guidelines are outlined in an informative brochure published jointly by Yukon DRR, Parks Canada, BC Parks, and the US NPS.

4.5.3 Cooperative Management

The third level of cooperation is referred to simply as cooperative management. Examples of cooperative management are normally directed by a formal agreement between two or more resource management agencies and may include involvement of end users/user groups or special interest groups. The agreements are often initiated because of a common management issue or shared resource, or in the instances of environmental cause and effect across jurisdictional boundaries.

The Mentasta Caribou Herd Cooperative Management Plan (Route, *et al.* 1995) is a good example of cooperative management in the St. Elias region. As will be discussed in Chapter 5, the Mentasta caribou herd is a small intermountain herd that ranges across a wide area administered by several different agencies. In response to an 80% decline in herd numbers the annual recreational hunt on Mentasta caribou was closed in 1989, the annual subsistence hunt on the herd was closed in 1992, and National Park Service staff at Wrangell-St. Elias National Park and Preserve, Fish and Wildlife Service staff at Tetlin National Wildlife Refuge, and regional biologists from ADF&G collaborated to develop a management plan for the herd. Despite varying management philosophies, the three agencies agreed on common management goals and objectives for the herd and formalized the plan in 1995. In addition, the cooperative plan lays out a series of guidelines rooted in population biology to be used in determining what type and how much hunting on the herd may occur. The plan also calls for extensive cooperative monitoring of the herd and necessitates open dialogue and communication between the three agencies. Local citizen advisory groups have endorsed the management plan and the Yukon Department of Renewable Resources will be consulted when the herd winters in Canada.

4.5.4 Joint Management

The most formal and complex level of cooperation evident in the St. Elias region is joint management. This type of cooperation places a heavy reliance on one or more formal agreements to maintain a very specific arrangement. Moreover, these agreements are very intricate and detailed in nature, and often have independent budgets established for their administration. The examples of joint management provided in Figure 4.3 are similar in that they were each initiated as a result of legislated requirements for public and/or first nation involvement in natural resource management. This is instructive in differentiating them from the examples of cooperative management which, although formal in nature, were established as a result of a shared resource or common management issues and are not legislatively mandated.

The settlement of aboriginal land claims in the Yukon has resulted in the establishment of a number of cooperative relationships in the St. Elias region that can be characterized as joint management. For example, the Kluane National Park management board is comprised of two members from the Champagne and Aishihik First Nation and two from Parks Canada. Two members of the Kluane First Nation will be added once their Final Agreement has been ratified. The board's mandate is "to make recommendations to the federal Minister of the Environment respecting all matters pertaining to the development and management of the park" (DIAND, 1993). A similar board, the Alsek Renewable Resources Council, is composed of three local representatives appointed by Yukon Renewable Resources and three representatives appointed by the Champagne and Aishihik First Nations. The Council's mandate is to make formal recommendations on the management of renewable resources on traditional territorial land outside of Kluane National Park. A similar resources council is anticipated to be established for the Kluane First Nation traditional territory.

Each of these bodies are still in their infancy and it is too early to accurately assess their effectiveness. Nevertheless, they have and will continue to significantly alter the manner by which land and resource planning and management is carried out around Kluane National Park and the greater St. Elias as a whole. What is also apparent is that the settlement of land claims in the Yukon has formalized the aboriginal first nation as a new level of government with a legislated right to participation in the management of natural resources.

4.5.5 International Agreements

International agreements are those cooperative relationships that have been initiated outside of the St. Elias region. They are directed by formal agreements to which the United States and Canada are signees and, therefore, to which management agencies in the

St. Elias region must adhere. Examples include Man and the Biosphere, IUCN agreements such as CITES, the International Joint Commission (IJC), and the International Migratory Bird Convention.

The most relevant of these in the St. Elias region is the World Heritage Convention to which both Canada and the USA are signees. Kluane and Wrangell-St. Elias became the first bi-national World Heritage Site in 1979, culminating nearly 15 years of formal negotiations between Canada and the US to establish an international park on the Alaska-Yukon Border (Eidsvik, 1983). Glacier Bay was added to the list in 1992, and The Tatshenshini-Alsek Wilderness was added to the site in 1994 soon after its establishment. An ancillary motive associated with these two latter additions was prevention of the Windy-Craggy mine, illustrating the more uncommon use of World Heritage designation as a tool in gaining protection for an area.

Within the spirit of the World Heritage designation, staff of the four parks communicate with each other and occasionally meet. Information sharing figures prominently in this communication and is primarily related to exchange of information on park resources. The potential for collaborating on interpretive activities was discussed at a 1996 meeting between interpretive staff from each of the four parks and future meetings have been planned. Of notable interest is a proposal by the Champagne and Aishihik First Nation to assign a common name to the World Heritage site that reflects the region's common characteristics.

4.6 SUMMARY AND DISCUSSION

The St. Elias region is unlike many other regions in that much of its area is composed of parks and protected areas. These areas range in the level of protection which is offered, from the four national parks and equivalent reserves which form the protected core of the region to peripheral wildlife sanctuaries and national forests. Management of these areas spans several federal and provincial/state/territorial agencies on each side of the international border. Land status and ownership outside of the parks and protected areas can be divided into numerous categories, adding an additional layer of complexity to the regional human-institutional environment.

Cooperation amongst all of these agencies occurs at a variety of levels, from simple informal communication to formal and complex agreements directing joint management of a particular resource or specific area. For the most part however, interagency cooperation throughout the St. Elias region is informal and although this type of cooperation can have numerous benefits, its success depends heavily on the individuals involved. Discussions with resource managers from numerous agencies across the St. Elias suggests that this presents a "Catch 22" situation. Without formal agreements for cooperation, the extent of interagency collaboration is entirely up to the individual involved. In addition, personality conflicts or rivalries between agencies can effectively eliminate informal cooperation. On the other hand, implementing formal agreements for cooperation can hinder the candid nature of such relationships, making their use less attractive in some instances. Despite these opposing realities, management staff throughout the region are generally of the opinion that formal agreements are necessary if interagency cooperation is to occur at a level beyond communication.

Several factors are responsible for limiting cooperation between agencies in Canada and the United States and these are discussed at some length in Chapter Seven. Yet there are just as many obstacles to increasing - or at least improving the effectiveness of - cooperation between agencies within the same country. Wildlife garners a substantial amount of management attention in the region, and it is quite instructive in demonstrating these barriers. For example, Valkenburg (1998) states that “the primary wildlife management problem in Alaska for caribou and other species is conflicting management authority between state and federal agencies” (pg. 126). Farnell *et al.* (1996) note similar conflicts in the Yukon, where the Territorial government and First Nations comanage wildlife resources, but where the federal government “retains jurisdiction over land, water, and timber resources, limiting the ability of Yukon to manage caribou habitats” (pg. 131). Because of its international nature and the number of different agencies involved, these problems are magnified several times in the St. Elias region.

As discussed in Chapter Two, coordinating management activities within broad cooperative programs that involve all relevant agencies and stakeholders is widely recognized as a fundamental component of ecosystem management. Activities such as the Prince William Sound-Copper River and Glacier Bay Ecosystem Initiatives provide evidence of the beginnings of such efforts within the St. Elias Region and the participatory decision making necessary in supporting such an approach can be found in the management board examples of Kluane National Park and the Tatshenshini-Alsek Wilderness Provincial Park as well as the Alsek Renewable Resources Council and

Regional Alaskan Subsistence Advisory Boards (Slocombe and Danby, 1998). However, management cooperation is typically carried out in the absence of formal coordinated efforts and is primarily single issue-oriented and/or single resource-oriented. This is particularly evident upon examination of cooperation between agencies on opposite sides of the international border.

To summarize, the need for management cooperation and the benefits obtained from it are acknowledged by agencies throughout the St. Elias region and numerous cooperative efforts have been implemented across the region. However, it appears as though a more integrated approach to resource planning and management in the St. Elias region would assist in reducing the difficulties associated with the fact that numerous agencies share management of the same resource or portions of the same ecosystem as well as the inherent shortcomings associated with the traditional approach of managing issues and resources in isolation of each other. Furthermore, such an integrated approach would provide an appropriate framework within which coordination of intergovernmental cooperation could occur and would assist agencies in identifying common issues and management concerns upon which new cooperative relationships could be built and existing relationships strengthened. Yet, given that integration of biophysical data and information from across the entire region has not been completed, it is impossible to accurately define where and how efforts at coordinating interagency cooperation should be focussed. As discussed in the first chapter, it is expected that the biophysical synthesis presented in the next chapter as well as the regional analysis presented in Chapter Six will assist in this process by identifying and characterizing those features and regional-scale processes shared across the region.

CHAPTER FIVE
REGIONAL BIOPHYSICAL SYNTHESIS

5.1 INTRODUCTION

This chapter presents the synthesis of information on biological and physical parameters collected from across the St. Elias region. It is not intended to provide an exhaustive reference on all aspects of the region; for such information the reader is referred to source information. The synthesis is, however, presented with the intent of illustrating key information about specific processes and features shared by the St. Elias Mountain Parks and their adjacent areas.

The maps presented in this chapter are intended to create a quasi-atlas of the broad-scale biophysical nature of the St. Elias Region. As outlined in Chapter 3, information on the maps has been synthesized from a wide variety of sources. The sources utilized in the creation of each map are presented in Appendix C along with specific methods utilized in generating each map and in amalgamating contrasting information (i.e. metadata). Except where noted, the maps represent the first time similar thematic information has been consolidated across the international border in the region.

It should be reiterated that the synthesis presented here is intended to provide a "snapshot" of ecological conditions in the St. Elias region over the past few decades. While the region's dynamic character is inherently recognized, the synthesis does not specifically characterize or analyze the type or frequency of change occurring over longer intervals.

5.2 PHYSIOGRAPHY

5.2.1 Tectonic Terranes And Neotectonic Setting

Given the size and geological complexity of the St. Elias region, the concept of *lithotectonic terranes* provides a useful framework for understanding its physical character and its development. Furthermore, the use of such a framework provides a platform for describing the occurrence of contemporary geological activity and processes.

Lithotectonic terranes or "accreted terranes" are large fault-bounded blocks of crustal rock characterized by a different geologic history than that of adjacent terranes (Gabrielse et. al., 1992; Plafker and Berg, 1994c). The juxtaposition of such dissimilar rock sequences throughout the North American cordillera is rather puzzling if it is assumed that this area shares the same geological history as the rest of North America. However, the advent of plate tectonic theory has provided a solid framework for an evolutionary interpretation of the cordilleran. In summary, such an interpretation asserts that the various terranes had completely different geological histories until they "drifted" via the mechanism of plate tectonics to collide with ancestral continental North America. These terranes likely originally existed as microplates or as islands of continental materials within the upper portions of an oceanic plate moving toward, and subducting beneath, the North American plate. When they collided with North America the terranes were, in essence, "scraped off" (Wilson, 1994) and accreted to the main continental plate. Initial hypotheses suggested that the prototerranes had originated far from the continental plate. However, modern interpretations hold that not all terranes have moved great distances and that, in fact, the paleogeographic relationship of most terranes remains largely hypothetical and, therefore, "suspect" (Coney *et al.*, 1980).

A significant amount of research over the past two decades has focussed on defining the lithotectonic terranes of the North American Cordillera on the basis of biostratigraphic, geological, metamorphic, structural, and paleomagnetic evidence (Plafker and Berg, 1994b; see Gabrielse and Yorath, 1992 and Plafker and Berg, 1994a for reviews). The result has been a relative agreement amongst geologists on the division of terranes and the location of major faults. While interpretive variances are inevitable, most of these occur by way of a division or aggregation ("lumping or splitting") of individual terranes, rather than radically divergent formulative hypotheses.

Figure 5.1 presents the arrangement of terranes in the greater St. Elias region as it is understood today and is an aggregation of maps delineating terranes for Alaska and the Canadian Cordillera. Detailed accounts of the progression of these terranes over time are given by Plafker and Berg (1994a) for Alaska and by Gabrielse *et al.* (1992) for Yukon and British Columbia. As the map illustrates, the St. Elias region is comprised of a number of terranes of various ages, each with their own formative history and distinct geology.

Adding to the diversity and complexity of the region's geology are areas known as post-accretion cover deposits. These areas represent younger rock of varying age which formed after accretion of the terrane(s) they overlie. One of the best examples of this is the Wrangell Volcanic Field, a 10,000 km^2 area of Cenozoic volcanic assemblages formed after accretion of the Wrangellia Terrane to the North American Continent.

As illustrated in Figure 5.2, modern evidence of tectonic processes is common

FIGURE 5.1 - TECTONIC TERRANES

(Located In Map Folio)

Key to Map 5.1 (Suspect Lithotectonic Terranes of the St. Elias Region)

Descriptions taken from Silberling *et al.* (1992) and Monger and Berg (1987).

(AXa, AXc) - Alexander Terrane: A geographically large terrane comprised of late Precambrian to Triassic strata. In the St. Elias Region, it can be divided into two distinct subterranes, each of which appear to have had an independent history prior to the Permian. The ***Craig Subterrane (AXc)*** is comprised of a relatively complete and undeformed sequence of Ordivician to Triassic succession of volcanic rocks - ranging from felsic (silica-rich) to mafic (iron-rich) - interstratified with mainly marine clastic and carbonate rocks. The ***Admiralty Subterrane (AXa)*** is distinguished by a coherent Paleozoic sequence of Devonian marine metabasalt and carbonate rocks (known as the Gambian Bay Formation) overlain by Late Devonian and Mississipian basaltic tuff and radiolarian chert (known as the Cannery Formation). Given their common history since the Permian, the Admiralty subterrane shares its post-Carboniferous features with the Craig subterrane.

(CG) - Chugach Terrane: An intensely folded yet weakly metamorphosed terrane comprised of Late Cretaceous graywacke and slate structurally interleaved with discontinuous assemblages of Triassic to Cretaceous blocks of mafic volcanic rocks, chert, gabbro, and limestone.

(GN) - Gravina-Nutzotin Overlap Assemblage: The Gravina-Nutzotin belt lies depositionally on both the Alexander and Wrangellia Terranes, linking the two into a "superterrane" in southeast Alaska. It is comprised mainly of Upper Jurassic to mid-Cretaceous argillite and graywacke, intermediate and mafic volcanic rocks, and granitic to ultramafic intrusive rocks. The assemblage may have acted as the protolith of the Kluane Terrane.

(KL) - Kluane Terrane: A metamorphic terrane composed of quartz-biotite schist (known as the Kluane Schist) probably formed in the Late Cretaceous. Although it is sometimes grouped with the Taku Terrane, and there is speculation that the late Mesozoic Gravina-Nutzotin is its protolith, its premetamorphic age is uncertain.

(MK) - McKinley Terrane: A thick sequence of Permian flysch overlain by Triassic chert and Upper Triassic pillow basalt, gabbro, and diabase. Upper portions are comprised of deformed flysch and chert of Late Jurassic to Cretaceous.

(PE) - Peninsular Terrane: A stratigraphically coherent sequence comprised of Permian Limestone, Upper Triassic limestone, argillite, and basalt, lower Jurassic volcanic and volcaniclastic rocks, and mid-Jurassic to Cretaceous marine sedimentaries. Major batholithic intrusions of Jurassic granites are found throughout the terrane.

(PN) - Pingston Terrane: A strongly folded yet weakly metamorphosed terrane comprised of Pennsylvanian and Permian phyllite, limestone, and chert, with deep marine limestone, shale, and siltstones of Upper Triassic age.

(PW) - Prince William Terrane: A thick, strongly deformed, assemblage of graywacke and argillite with minor conglomerate, pillow basalt, basaltic tuff, and dike rocks, intruded with Middle Eocene gabbro, tonalite, and granodiorite.

(SE) - Saint Elias Terrane: A fault-bounded block of metamorphosed volcanic and sedimentary rocks, probably Late Mesozoic in age, comprised mainly of quartz-mica schist and gneiss. It may be a structurally disconnected equivalent of the Chugach Terrane.

(ST) - Stikinia Terrane: A coherent terrane comprised of stratigraphically stacked Mississipian, Permian, Triassic, and Jurassic marine and nonmarine volcanic and sedimentary strata and coeval intrusions.

(TA) - Tracy Arm Terrane: A metamorphic terrane of pelitic and quartzofeldspathic schist and paragneiss, marble, amphibolite, and some serpentinite. Premetamorphic stratigraphy is unknown, and protolith ages are uncertain in the greater St. Elias Region, although strontium isotope studies suggest the Late Proterozoic.

(TU) - Taku Terrane: The Taku Terrane is "an enigmatic, possibly polygenetic assemblage of multiply deformed and metamorphosed strata" (Monger and Berg, 1987, pg. 8). It contains variably metamorphosed upper Paleozoic and triassic basalt and local felsic volcanic, carbonate, and pelitic rocks and includes undated metamorphosed clastic and volcanic rocks similar to the Jurassic and Cretaceous strata of the Gravina-Nutzotin belt. The Taku Terrane appears to comprise three distinctive assemblages, the northernmost which lies in the St. Elias region and is differentiated from the more southern assemblages by Upper Paleozoic basaltic volcanic and volcaniclastic rocks.

(WR) - Wrangellia Terrane: A stratigraphically coherent terrane with local deformations and metamorphisism. Its base is formed by a thick assemblage of late Paleozoic volcanic rocks overlain by a succession of Permian limestone and shales, and cherts of Late Permian to Middle Triassic age. These are overlain by a very thick sequence of greenstones metamorphosed from both subaerial and submarine basalts which are in turn overlain by Triassic limestones and other calcareous rocks. In the St. Elias Region, Jurassic and Cretaceous rocks are primarily sandstones and shale. More recent layers in the northwestern portions of the St. Elias region are comprised of Tertiary and Quaternary lavas issued from the existing Wrangell Mountains.

(WM) - Windy-McKinley Terrane: A composite of the Windy and McKinley terranes composed of ultramafic rocks, Devonian limestone, Permian chert, and Triassic pillow basalt.

(WY) - Windy Terrane: A disrupted assemblage of sepentinite, basalt, metachert, and blocks of Devonian limestone and shale, all in a matrix of upper Mesozoic conglomeratic flysch.

(YA) - Yakutat Terrane: A terrane comprised of Upper Mesozoic graywacke and shale deposits with structurally interleaved masses of disrupted chert, argillite, and volcanic rocks as well as Eocene basalt and shale.

(YT) - Yukon-Tanana Terrane: The Yukon-Tanana is a large heterogenous metamorphic terrane underlain by a basement of Precambrian gneiss. It is comprised predominantly of quartz-mica schist, quartzite, metaquartzite grit, mearhyolite, and minorophiolitic rocks and marble. Protolith ages are estimated at the middle Paleozoic for igneous rocks and Devonian for carbonates. The final metamorphic event is estimated to have occurred in the Late Mesozoic.

FIGURE 5.2 - NEOTECTONIC SETTING

(Located In Map Folio)

throughout the St. Elias region. Several active continental faults cross the entire region, including the Hubbard, Border Ranges, Totshunda, Fairweather, and Denali faults. Earthquake activity is amongst the highest in North America. Excluding off-shore earthquakes, the region has experienced more than 250 earthquakes of magnitude 4.0 or greater in the past 25 years. Many of these earthquakes, and indeed the majority of those located offshore, are associated with the active collision of the Yakutat Terrane and its accretion with North America (Burns, 1983). Volcanic and geothermal features and processes remain evident throughout the Wrangell Volcanic Field (Richter *et al.*, 1990). While Mt. Wrangell itself is the only volcano active today, eruptions from other mountains in the area are known from as recently as 1,250 years ago (Richter *et al.*, 1995). Mud volcanoes and hot springs are additional contemporary geothermal features associated with the Wrangell Volcanic Field.

5.2.2 Relief And Physiographic Divisions

The geological processes that have occurred over the past 200 million years in the St. Elias region have created a landscape like no other in the world. The region contains the highest concentration of tall mountains in North America and includes the steepest ascent from sea level in the world (Icy Bay to Mt. St. Elias is a 5,489 m climb in just under 24 km). Deep valleys weave throughout the region, dividing it into separate ranges and individual mountain blocks. This is well illustrated in Figure 5.3 which shows elevation and relief of the region. Regionally significant among these are the valleys of the Alsek and Copper rivers which are the only major valleys to cross the coastal mountain barrier,

FIGURE 5.3 - ELEVATION

(Located In Map Folio)

the Chitina River valley which runs through the heart of Wrangell-St. Elias National Park and Preserve, and the Shakwak Trench which follows the eastern edge of Kluane National Park and Wildlife Sanctuary. Each of these valleys branches into or receives numerous smaller valleys and, with the exception of the Chitina, are shared by several jurisdictions.

Based primarily on character of relief, but also on other characteristics such as soils and geology, Map 5.4 illustrates the physiographic divisions of the greater St. Elias region and adjacent areas as identified by several different geographers and geologists. The map supplement describes each of the divisions. It is evident from the map that the ranges of the St. Elias Mountains occupy much of the four core protected areas. It is also evident that these protected areas share several other divisions with their adjacent areas. The Wrangell Mountains and Icefield and Fairweather Ranges are the only divisions completely encompassed by one or more of the core protected areas while the remaining ranges of the St. Elias Mountains as well as the Mentasta-Nutzotin Mountains are nearly completely encompassed.

5.3 CLIMATE AND HYDROLOGY

5.3.1 Climate

The latitudinal position of the St. Elias Region, its proximity to the Gulf of Alaska, the topographic nature of the region, and the high altitudes of the St. Elias, Chugach, and Wrangell Mountains are the four dominant influences on the climate of the St. Elias Mountain Parks (Webber, 1974). Yet, despite the specificity in how each of these factors influences regional climate, it is actually the complex interactions between these variables

FIGURE 5.4 - PHYSIOGRAPHY

(Located In Map Folio)

Supplement to Map 5.4 (Physiographic Divisions of the St. Elias Region)

Shakwak Trench (2,950 km^2)
The Shakwak Trench is a long valley that separates the Yukon Plateau from the St. Elias Mountains, marking the location of the Denali Fault System. It lies on an axis of approximately 120°-300° from Kusawa Lake, along Kluane Lake, to beyond the White River, where it gradually disappears in the broad Tanana River Valley in Alaska. In total, the trench is approximately 300 km long and is over 15 km wide in some sections. The valley drains in two directions, the divide being located just south of Kluane Lake where a maximum floor elevation of approximately 3500' is reached. In Pleistocene time the Shakwak Trench received ice from the glaciers of the St. Elias Mountains and today contains large drift deposits as well as evidence of heavy scouring.

Kluane Plateau (20,520 km^2)
The Kluane Plateau is a highly variable region that is divisible into several distinct parts, although these are not illustrated on the map. This includes an area of high tablelands (>5,500') southeast of the Takhini and Dezadeash Rivers that is dissected by a network of deep valleys. Northwest of these rivers the Aishihik basin, a largely drift covered topographic depression, covers a large portion of the Kluane Plateau. The basin is bordered to the west by two northwest trending mountain ranges - the Ruby and Nisling Ranges - each of which exceed elevations of 6000'.

Klondike Plateau/Yukon Tanana Upland (109,000 km^2)
Despite its large size, most terrain within the Klondike Plateau/Yukon Tanana Upland shares a striking topographic similarity that appears to be due to the absence of Wisconsian glaciation. In Bostock's (1948) words, the entire area is "a maze of deep , narrow valleys separated by long, smooth-topped ridges whose elevations are very uniform, and which are remnants of an old uplifted erosion surface" (pg. 69). The valley of the Yukon River is a prominent feature of the region.

Teslin Plateau (28,200 km^2)
The Teslin Plateau is an area of high tablelands that have an undulating surface with elevations generally between 4,500 and 5,000'. It is dissected by a network of large valleys, such as those occupied by the Teslin and Lewes Rivers with bottom elevations of between 2,100 and 2,300'. In its western portions, the Teslin Plateau rises gradually to meet the northern reaches of the Boundary Ranges. With the exception of its very highest peaks, the entire Teslin plateau was covered by Pleistocene glaciers.

St. Elias Mountains (57,200 km^2)
The St. Elias Mountains constitute the largest group of high mountain peaks in North America and contain eight of the continent's 15 highest peaks. The entire range follows a northwest to southeast trend, with its eastern boundary following the Denali Fault, and can be subdivided into five sets of ranges and one intermountain valley. These six subdivisions total more than 57,000 km^2 and form the core of the greater St. Elias region.

The ***Kluane Ranges (4,100 km^2)*** mark the eastern and northern fronts of the St. Elias Mountains, rising abruptly from the low elevation Shakwak trench along the Denali Fault system. Large crosscutting valleys divide the Kluanes into several short distinct ranges which, for the most part, consist of two or three parallel ridges connected by high saddle-like depressions. Mountain slopes in these ranges are generally steep and there is relatively little variation in peak elevations. Many are nearly 7,000', with the highest peaks roughly 8,000'. Alpine glaciers are intermittent throughout these high peaks.

The ***Duke Depression (2,700 km^2)*** is an intermountain plateau-like belt characterized by broad slopes. For most of its length, the Duke Depression runs roughly parallel with the Kluane Ranges and marks the boundary between it and the Icefield Ranges. Like other major intermountain valleys in the greater St. Elias, the Duke Depression marks the location of a major fault line, the Duke River Fault. The depression extends westward into Alaska where it narrows to mark the division between the Wrangell Mountains and Alaska Ranges.

The ***Icefield Ranges (34,200 km^2)*** comprise the main body of the St. Elias Mountains and, with the exception of Mt. Fairweather, contain all of its highest peaks. In general form, these ranges appear as a high plateau surmounted by the high peaks and deeply dissected by extensive valleys. Invariably these valleys are filled high with snow and ice, forming the immense glacial icefield of the St. Elias region.

The ***Alsek Ranges (8,500 km^2)*** lie south of the Kluane Ranges and southeast of the Icefield Ranges, occupying a large portion of the Haines Triangle. Like the Kluane Ranges, the elevation of most high peaks are relatively constant, and normally fall within a range of 6500' to 8000'. High plateaus between these peaks are covered in extensive glacial ice. The broad valley of the Tatshenshini River divides the Alsek Ranges into two distinct portions, although the physical characteristics of the two areas are quite similar.

The ***Fairweather Range (5,400 km^2)*** marks the southwestern backbone of the St. Elias Mountains and acts as a steep, unbroken barrier between the Pacific Ocean and Glacier Bay. Most high peaks exhibit a characteristic pyramid shape with sharp angular ridges and steep summits. Peak elevations range greatly with the highest being Mt. Fairweather at 15,300'. Permanent snow and ice dominates much of the Fairweather Range and the entire range is drained by glaciers which discharge into the Pacific Ocean or Glacier Bay.

Finally, the ***St. Elias Coastal Range (2,300 km^2)*** constitutes the western foothills of the Fairweather Range. While they are not often considered a distinct range of the St. Elias Mountains, they are significantly lower in elevation and different in topographic character than the Fairweather Range and Icefield Ranges. These coastal mountains are covered in ice and drained entirely by glaciers.

Wrangell Mountains (14,500 km^2)

The Wrangell Mountains are a compact cluster of volcanic mountains that rise high above the Copper River lowland to its west and the Chitina Valley to its south. The Wrangells contain several of the continent's highest peaks, including Mt. Sanford (16,237'), Mt. Blackburn (16,523'), and Mt. Wrangell (14,163') which is the only volcano active today. Numerous other peaks exceed 10,000'. In general character the Wrangell Mountains are steep and rugged, with most slopes exceeding 7° and many surpassing 15° (Gallant *et al.*, 1995). Much of the central high elevation terrain of the Wrangell Mountains is covered by glacial ice which drains in all directions *via* large valley glaciers and streams. The narrow Chitistone Valley and Pass is often used as a convenient division between the Wrangells and the St. Elias Mountains.

Boundary Ranges (60,000 km^2)

The Boundary Ranges comprise the long chain of mountains that make up the westernmost portions of mainland British Columbia and southeast Alaska north of Dixon Entrance and the mouth of the Nass River (55°N). Following a north-south lineament, the Boundary Ranges are dissected by a network of deep, U-shaped valleys with floors that are often quite low in elevation, resulting in the high relief for which these mountains are noted. A large part of these mountains are covered in glaciers, much of it along the international border. The Taku and Stikine Rivers occupy the only two major valleys to cut across the central portion of this mountain chain, although and fjords are extensive along the coast. The Boundary Ranges reach their northern terminus in the greater St. Elias region, where elevations rarely exceed 8000'.

Southeast Alaska Coastal Foothills (33,900km^2)
The coastal foothills of southeast Alaska form the western flank of the Boundary Ranges, although the division between these two areas is rather indistinct. The foothills consist of blocks of high mountains separated by flat-bottomed, often submerged, valleys. Although high peaks are generally angular, “those less than 3,500' were completely glaciated and have rounded summits” (Wahrhaftig, 1965, pg. 43).

Chilkat-Baranof Mountains (23,000 km^2)
The Chilkat-Baranof Mountains are a topographically diverse highland occupying Chichagof and Baranof Islands in southeast Alaska and extending northward along the western edge of the Lyn Canal. The Chilkat Mountains occupy the portion of the physiographic region north of Icy Straight, while the Chichagof Highland and Baranof Mountains fall to the south. Because of this topographic discontinuity, the region has been classified in a variety of fashions. Mathews (1986) classified this range as a southern extension of the St. Elias Mountains while Wahrhaftig (1965) included the Alsek Ranges of the St. Elias Mountains as part of the Chilkat-Baranofs Mountains.

Copper River Lowlands (16,800 km^2)
The Copper River Lowlands are an expansive area of low-lying terrain, with elevations varying between 420 and 900 m. The region occupies the site of a large lake that existed during glacial times and much of it is covered in lacustrine deposits that range from tens to hundreds of metres thick. Lower stretches of many of the region’s larger rivers cut deeply into this overburden, resulting in narrow valleys with steep banks. The Copper River lowlands can be divided into two general areas. The ***Copper Basin*** occupies the main body of the region and lies west of the Wrangell Mountains. In the western portions of this area, the permafrost table is close to the ground surface, resulting in abundant thaw lakes (Gallant *et al.*, 1995). The ***Chitina Valley*** is an eastward extension of the Copper River Lowlands that marks a wide division between the Wrangell and Chugach Mountains. This valley contains numerous morainal ridges that flank the river and rise above its glacial outwash plains (Wahrhaftig, 1965).

Kenai-Chugach Mountains (73,280 km^2)
The Kenai-Chugach Mountains physiographic region form “a rugged barrier along the north coast of the Gulf of Alaska” (Wahrhaftig, 1965, pg. 40). The Chugach Mountains are those most relevant to the St. Elias region. These mountains are dominated by east-west trending ridges of 7,000-13,000 feet in altitude. They have been heavily glaciated and still retain massive icefields that radiate large valley and piedmont glaciers. The north front of the mountains rises abruptly from the Copper River Basin and Chitina River Valley.

Coastal Forelands (13,000 km^2)
The Coastal Forelands rim much of the Gulf of Alaska. Wahrhaftig (1965) describes the region as “a coastal plain marked by longitudinal beach and dune ridges, crossed in places by outwash plains and by belts of morainal topography and backed by marine terraces as high as 800' in altitude” (pg. 41). While much of the coastline is straight, it is marked by occasional fiords. Three major subdivisions can be recognized: the Yakutat Forelands south of Yakutat Bay; the Malaspina Forelands, between Yakutat Bay and Icy Bay; and the area between Icy Bay and the Copper River Delta, referred to here as the Bering Glacier Forelands.

Northway-Tanacross Lowlands (11,000 km^2)
The southern edge of the Northway-Tanacross Lowlands runs parallel with the inner-most ridges of the

Pacific Mountain System and appears to act as a wide continuance of the Shakwak Trench. In its eastern portions, the lowlands include the Wellesley Lake Basin in the Yukon which abuts the Nisling Range of the Kluane Plateau. Its northern edge rises abruptly to meet the higher elevation Klondike Plateau/Yukon-Tanana Upland. Low rolling hills dot the low elevation basin, which rarely exceeds elevations of 2500'.

Mentasta-Nutzotin Mountains (6,800 km^2)
The Mentasta and Nutzotin Mountains are the easternmost subunits of the Alaska Range, and meet the Kluane Ranges at the White River. The mountains consist of a single axial ridge running in a southeast-northwest direction that is dissected by the valleys of the Chisana and Nabesna Rivers, the latter of which marks the division between the two ranges. The mountains rise abruptly from the Northway-Tanacross Lowlands, particularly the Nutzotins, and are separated from the Wrangell Mountains by valley glaciers and passes. Glaciers dot the high peaks of the Nutzotin Mountains.

Glacier Bay Depression (1,600 km^2)
The Glacier Bay Depression is a largely submerged lowland that contains isolated, very rounded, mountains. For the most part, it has only recently (<200 years) been released from the cover of glaciers. The St. Elias and Chilkat Mountains flank the depression while Icy Straight demarks its southern boundary.

that is responsible for climate and weather patterns in the St. Elias region.

The St. Elias Region spans two broad climatic zones: the coastal-maritime zone and the sub-arctic continental zone. The sub-arctic continental zone is characterized by "large annual, day-to-day, and daily ranges in temperature, low to moderate atmospheric moisture content, and moderate or light and irregular precipitation" (Wahl *et al.*, 1987, pg. 33). In contrast, the coastal-maritime zone is characterized by much smaller variations in temperature, high atmospheric moisture content and regular precipitation (Bailey, 1995). Taylor-Barge (1969) examined the nature of the transition between the two climate zones and concluded that:

> "It appears that temperature, cloud, and precipitation considerations definitely point to the existence of some form of climatological divide. The divide does not take the form of a blockage of air mass and frontal systems, but is instead a complex modification of the systems or their surface effects. The divide is not a simple line but rather a zone much like a synoptic front, though probably much broader. The effectiveness of this divide appears to die out above 10,000' in the free atmosphere." (pg. 40).

The measured differences between the two zones are a result of the interaction between moist air from the Gulf of Alaska and the high coastal barrier presented by the St. Elias, Chugach, and Coast Mountains. Intense low pressure cells develop frequently over the Gulf and act as the primary source of precipitation for the region. As these systems move overland a classic orographic front is created. Figures 5.5a and 5.5b present data from the 27 permanent and semipermanent climate stations across the greater St. Elias region. As illustrated in the figures, coastal areas receive extremely heavy precipitation with some areas recording over 3000 mm annually. Precipitation consistently falls as

FIGURE 5.5 - AVERAGE ANNUAL PRECIPITATION AND TEMPERATURE

(Located In Map Folio)

snow as these air masses ascend the coastal mountain barrier[2].

Wahl *et al.* (1987) estimate total annual precipitation in portions of the Icefield Ranges to exceed 3000 mm with all of this falling as snow above 2500 m. As part of the "Icefield Ranges Research Project" which spanned the 1960s, Marcus and Ragle (1972) measured snow accumulation on the Seward Glacier in the Icefield's interior as 5800 mm (a water equivalent of 2,120 mm) in the winter of 1964-1965. Given that much of the moisture contained in these air masses falls on the Gulf coast and high mountains, areas further inland experience a rainshadow effect with significantly less precipitation. This is clearly illustrated on Figure 5.5a.

At a finer scale, certain landscape features have significant influence on local climate. For example, the valleys of the Alsek and Copper Rivers funnel warm moist air from the Gulf to the interior, creating broad microclimates and altering local weather patterns; Kluane and other large lakes have a moderating effect on local climate; valley glaciers funnel cold air and strong winds from the interior icefields to surrounding areas; and cold air tends to settle in the Shakwak Trench, Chitina Valley and other deep mountain valleys (Webber, 1974; NPS, 1986; Gray, 1987; Wahl *et al.*, 1987).

At a local scale, topographic variability induces climatic variability associated with differences in slope and aspect. In addition, given that air temperature drops approximately 0.65° C every 100 m (Gray, 1987), climatic conditions are often very different at higher elevations, creating the altitudinal zonation observed in all mountainous

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[2]As a note of extreme, Yakutat received over 4,500 mm of precipitation in 1964 (Marcus and Ragle, 1972).

regions. With a mean latitude of 61° N, the St. Elias region experiences marked seasonal differences in daylight hours. Furthermore, the intensity of solar radiation is significantly less than at middle and low latitudes because of the oblique angle of the sun. Combined with the mountainous topography, this can result in persistent shade conditions in some valleys, further altering the microclimate of an area (Gray, 1987).

5.3.2 Glaciers

Persistent accumulation of snow has created a mass of ice that, as illustrated in Figure 5.6, is the predominant surficial feature of the St. Elias region. Much of the region has, at one time or another, been covered by this ice mass and a large percentage of the geomorphological features observed in the region are either directly or indirectly associated with the advance or ablation of glaciers originating from these mountains (Mann, 1986; Molnia, 1986; Rampton, 1981). Molnia (1986) places the last major episode of late Pleistocene ice retreat for the area between 12,000 and 15,000 years ago. However, the dynamic nature of the region's glacial environment has meant that local advances and retreats have continued since. The best known of these are associated with the bays on the Gulf of Alaska Coast. Icy Bay, Yakutat Bay, and Glacier Bay have each experienced multiple advances of ice over the past 10,000 years which have, in some instances, covered them entirely (Mann, 1986; Molnia, 1986; Walker and Zenone, 1988).

Present glacial activity in the St. Elias region takes place on four scales: the icefields, piedmont glaciers, valley glaciers, and cirque/niche glaciers. The icefields of the St. Elias region are vast bodies of thick ice that fill intermountain valleys in the core of the

FIGURE 5.6 - GLACIERS

(Located In Map Folio)

Wrangell and Chugach Mountains and the Icefield and Fairweather Ranges of the St. Elias Mountains. These areas represent the bulk of ice stored in the region and can exceed thicknesses of 1000 m (Dewart, 1970).

Piedmont and valley glaciers are fed by and extend outward from the icefields. Piedmont glaciers spill into broad unconfined areas which, during Pleistocene glaciation, included all outlying areas but is limited now primarily to the Gulf of Alaska coastal plain. The Malaspina and Bering Glaciers are classic examples, each having areas exceeding 2500 km^2. Valley glaciers move along the axis of mountain valleys, giving them their name and characteristic finger-like form. The valley glaciers of the St. Elias region are some of the longest and most active in the world.

Cirque and niche glaciers constitute the smallest scale of glacial activity in the St. Elias region. These small glaciers persist independent of the large icefield masses, although they dot many of the high altitude mountain peaks that rise above the icefields.

5.3.3 Drainage

The surface hydrology of the St. Elias region is very much a function of its landscape and climate. As illustrated in Figure 5.7, the icefields and their radiating valley glaciers are a source for all of the major watersheds in the region. These watersheds drain in one of two directions: to the Bering Sea *via* the Yukon River, or south to the Gulf of Alaska. Wrangell-St. Elias NP&P and Kluane NP sit on the cusp of this continental divide and contain watercourses draining in both directions. Drainage divides are, however, poorly defined in some areas - particularly in the central icefields where frozen conditions prevail,

FIGURE 5.7 - DRAINAGE AND MAJOR WATERSHEDS

(Located In Map Folio)

and in the Tetlin Flats and western portions of the Copper River Lowlands which are virtually flat and where wetlands are predominant.

The character of stream flow in the St. Elias region is due primarily to glacial sources. The Chitina River for example, averages a discharge estimated at over 560 m^3/s - yet 85 percent of its annual discharge occurs between May 1 and October 31 when warmer temperatures prevail (NPS, 1986). Diurnal variations in discharge are also common during this season with peak flows occurring in late afternoon. These annual and diurnal variations result in the braided nature of virtually all rivers in the region. Furthermore, many of these rivers carry high levels of suspended sediment due to their glacial source and erosive capability.

The drainage patterns of the St. Elias region are incredibly dynamic at all scales. Stream courses change constantly due to the variations in discharge and the dynamic nature of the landscape and glacier-dammed lakes of various size are relatively common in the region. Many, such as Hazard Lake in Kluane National Park, and Oily Lake in Wrangell-St. Elias fill and drain annually, while others follow a much longer return interval (NPS, 1986; Gray, 1987). One of the best known examples of these is Lake Alsek which has been created at least five times in the last 3,000 years by the damming of the Alsek river by the Lowell Glacier (Clague and Rampton, 1982). Evidence such as driftwood and beach deposits indicates that the most recent damming (ca. 1850) created a lake extending up the Dezadeash River above Haines Junction. Wave-cut terraces, sediment cores, and traditional knowledge passed on by the local first nations suggest the lake drained by way of a catastrophic outburst flood in less than 48 hours (Clague and Rampton, 1982).

5.4 LANDCOVER AND VEGETATION

The mapping and characterization of major ecosystems and vegetation communities has been undertaken at a wide variety of scales using very different classification systems. The end result is that it is virtually impossible to integrate any of these existing systems into a single mapped classification of vegetation communities and/or ecosystems for the entire St. Elias region. As such, a direct comparison between each protected area cannot be undertaken. However, the state of existing information does prove useful in characterizing regional patterns, if only at a very general level.

It should be noted that ecological land classification (described in Chapter Two) has been completed for each of Yukon, Alaska, and British Columbia. However, these classifications do not typify landcover or vegetation communities but, instead, regionalize a given area into a nested spatial hierarchy using integrated sets of criteria. For this reason, ecological land classification is discussed in Chapter Six.

The Alaska Land Use Planning Commission (LUPC, 1973) classified the state of Alaska into nine broad vegetation types and mapped these areas at a scale of 1:2,500,000. At a similar geographic scale, but a much higher resolution, biogeoclimatic zones have been delimited at a scale of 1:250,000 for the entire province of British Columbia (BC MOF, 1992). These regions are based on a classification system using three major variables: climate, vegetation, and physiography and represent the most detailed ecological classification system available for the Tatshenshini-Alsek Wilderness and surrounding areas of British Columbia. Digital versions of each of these maps were obtained from the USGS and BC MELP respectively and built into the regional GIS. Statistical query of the maps facilitated the breakdown of the relative proportions of each Alaskan ecosystem and BC biogeoclimatic zone presented in Appendix D.

A qualitative comparison of these ecosystem classifications reveals several distinct regional patterns with respect to basic landcover and generalized ecosystem types. First, using the basic elevational zonation of montane, subalpine, and alpine, it is evident that the alpine zone figures prominently in each of the four core protected areas, while it is less prominent in surrounding areas. Conversely, the montane zone comprises the bulk of adjacent unprotected areas. This is well illustrated in Figure 5.8 which illustrates regional forest cover. Statistical query of basic land cover map layers created for the regional GIS from the 1:250,000 topographical base maps resulted in the breakdown of land cover types presented in Table 5.1 and also illustrates this spatial pattern of landcover distribution.

Figure 5.8 and Table 5.1 also confirm that wetlands are not evenly distributed in the St. Elias region but tend to occur in large complexes. Two major types of complexes are evident based on their geographic location - coastal and interior. Significant interior complexes include the Tetlin Flats and Copper River Lowlands while significant coastal complexes include the Copper River Delta area and the Yakutat Forelands. Each of these areas, along with the Wellesley Lake Basin in Yukon, are dotted with innumerable lakes of small to medium size.

Vegetation classification has been completed at a more detailed scale for several portions of the St. Elias region. Using aerial photograph analysis and intensive field investigations, Shephard (1995) classified and mapped 60 vegetation communities in nine

FIGURE 5.8 - FOREST COVER AND WETLANDS

(Located In Map Folio)

Table 5.1: Basic Landcover in the St. Elias Region

		Percent of Total Area					
	Total Area (km)	Permanent Snow and Ice	Isolated Alpine Nunataks	Forest	Open Water(1)	Major Wetlands	Other(2)
Kluane National Park	22013	52.4	11.5	7.5	0.8	0.2	27.6
Wrangell-St. Elias National Park	53420	35.2	5.6	18.7	1.3	0.1	39.2
Glacier Bay National Park	13355	30.9	9.1	20.3	19.5	0.0	20.3
Tatshenshini-Alsek Wilderness	9580	37.9	6.8	8.5	0.6	0.0	46.2
Tetlin National Wildlife Refuge	3739	0.1	0	61.6	6.3	18.5	13.5
Kluane Wildlife Sanctuary	6368	10.3	2.1	42.8	0.6	0.2	44.0
Yakutat Block (Tongass NF)	5273	35.7	6.3	24.0	6.5	4.1	23.3
Icy Bay to Valdez	15550	36.9	4.5	21	6.5	5.1	26
Copper River Watershed (unprotected portions east of 147°)	21710	5.4	0.4	34.6	3.8	1	54.9
Lynn Canal Area	13180	28.6	3.8	28.4	13.9	0	25.2
Shakwak Trench & Kluane Plateau	23480	0.0	0.0	74.7	4.3	0.6	20.4

(1) Includes marine bays and inlets
(2) Primarily alpine and subalpine shrub, grass, and forbs, but unidentifiable at this scale.
Source: Calculated *via* the regional GIS. (Areal units used for analysis are illustrated in Appendix D)

landscape associations across the Yakutat Forelands. Douglas (1980) used a similar methodology to divide the green belt of Kluane National Park into 35 *land system units* based on recurring patterns of landforms. These were then divided into 109 vegetation communities based on dominant species present. Using remotely sensed data, Campbell et al. (1997) mapped two-thirds of Wrangell-St. Elias, classifying the area into 33 land cover types and vegetation communities. A similar methodology was utilized by Talbot *et al.* (1984) for the entire Tetlin NWR which was classified into 16 land cover types and vegetation communities at a resolution of 2500 m^2 (i.e. 50m x 50m pixel). All of the Chugach and Tongass National Forests have been classified by the National Forest Service using similar methodologies.

One of the most apparent features of these and other vegetation classifications is that the scale at which the system is examined largely determines the number of vegetation communities which are identified. While the use of a regional perspective reduces the number of identifiable communities, it must be recognized that an innumerable number of biophysical variables influence the expression of vegetation communities at any given location. What may appear as a relatively homogenous unit at a scale of 1:250,000 may actually be comprised of several different communities when examined at a scale of 1:50,000.

All areas of the St. Elias region exhibit a certain degree of altitudinal zonation with respect to vegetation. Forested ecosystems give way to subalpine zones of tall shrubs at higher elevations which, in turn, give way to alpine meadows and tundra at the highest elevations. While this is the general pattern observed, the specific patterns vary considerably across the region. For example, the low elevation forests of the Shakwak Trench are different from those of the upper Copper River basin which are, in turn, very different from those present along the outer coast.

An examination of the basic vegetation groups and dominant species present within each of the four national parks and equivalent reserves illustrates the differences and similarities throughout the region and is presented in Table 5.2. As a point of background to the table, it should be recognized that each of these protected areas can be divided into a number of subsystems based on floristics. Vegetation communities in the interior of Wrangell-St. Elias, encompassing the Wrangell Mountains and Chitina Valley area, are substantially different from coastal areas and the Chugach Mountains. Vegetation communities in the northern areas of Kluane National Park are different than those in the southern area of the park, due primarily to differences in precipitation. Similarly, vegetation in the drier interior portions of the Tatshenshini-Alsek Wilderness are different than those in the lower reaches of the Alsek River valley and the Chilkat Pass. To a slightly lesser degree, differences also exist between the vegetation communities of Glacier Bay National Park's outer coast and the less exposed areas around Glacier Bay itself. These areas are referred to in the table and provide a natural framework for comparison.

5.5 SPECIES DIVERSITY

Information on species diversity from each of the protected areas was aggregated by developing the species lists for mammals and birds contained in Appendix E. No attempt was made to assess any expression of diversity other than species richness as mere

Table 5.2: Basic Vegetation Characteristics of the St. Elias Mountain Parks

Representative Montane Zone Forest Communities			
Kluane NP(1)	**WRST NPR(2)**	**GLBA NPR(3)**	**TAT-Alsek PP(4)**
The valleys and lower slopes of the Kluane Ranges (up to 1100 m) are dominated primarily by continuous forests of white spruce. Closed canopy types occur on mesic sites and have a continuous moss-lichen herbaceous layer. Open canopy types occur on drier sites and have sparse herbaceous layers. Woody species associated with these spruce communities include shrub birch, grayleaf willow, and buffaloberry. The wettest areas typically have large numbers of white birch. Deciduous forests comprised of trembling aspen, balsam poplar, and/or Scouler's willow are more common on well drained, course alluvial deposits occurring in valley bottoms and in early successional areas.	Forest communities extend as high as 4000' in interior areas. Montane valleys are typically dominated by white spruce. Forests of white spruce, birch, balsam poplar and trembling aspen dominate well drained upland sites. These areas have low shrub understories typically including prickly rose and buffaloberry. Poorly drained flat terrain in perimeter areas of the park/preserve are dominated by forests of black spruce. Forests on permafrost are typically open canopy with a tall shrub understory dominated by willow and birch and/or a thick herbaceous layer dominated by mosses, sedges, and grasses. Coastal forests are very different than interior. Timberline averages 2,000'. Lowest communities are dominated by Sitka spruce and western hemlock with understories of salmon berry and devil's club. Mountain hemlock and coastal subalpine fir are most common at higher zonal elevations.	Forests dominated by sitka spruce and western hemlock extend from sea level to about 2000' in fair to well drained areas. Mountain hemlock becomes most abundant at higher forested elevations near timberline. Black cottonwood and sitka alder are frequent forest components along streams, rivers and beach fringes. Understory vegetation is lush and consists of a variety of ferns and other herbaceous species, a thick moss layer, and devil's club. Poorly drained areas are open-canopied and comprised of mountain hemlock with understories of shrubs, sedges and mosses. Lodgepole pine is frequent among these communities.	Alsek Valley forests above the Tweedsmuir Glacier are very similar to the white spruce forests of Kluane. Forest communities on the valley bottoms of the upper and middle Tatshenshini are typically open canopied, with balsam poplar common on the floodplains and lower mountain slopes. Open areas are dominated by willows, alder, and buffalo-berry. Closed forests of white spruce, white birch and trembling aspen cover valley slopes. Valley-bottom forests of the mid Alsek and lower Tatshenshini Rivers as well as the lower Alsek down-valley of their confluence are wetter and more dense in structure than upstream due to a coastal influence. Conifers are generally absent along valley slopes in this area. Forests in the Chilkat River drainage and Tarr Inlet drainage are very different, dominated by western hemlock at elevations up to 2000 feet and mountain hemlock at elevations up to 3500 feet

Table 5.2 (cont.): Basic Vegetation Characteristics of the St. Elias Mountain Parks

Typical Subalpine Zone Communities			
Kluane NP(1)	**WRST NPR(2)**	**GLBA NPR(3)**	**TAT-Alsek PP(4)**
The subalpine zone is dominated by tall (up to 3-4 m) shrubs. Willows are the dominant shrub type with dwarf birch a subdominant species. Scattered individuals of white spruce are common throughout the zone, the upper limit of which extends to about 1350 m. Alders are also present in the subalpine, but only in the wetter southern areas of the park. In these areas the subalpine is often interrupted by lush herbaceous meadows while herbaceous subalpine meadows in central and northern areas are much drier.	Subalpine communities in the interior consist mainly of resin birch and/or willow 1 to 2 metres high interspersed with lichens and moss. The subalpine zone in coastal areas is usually dominated by alder and salmonberry interspersed with coastal subalpine fir. More open areas dominated by copper flower are also common.	Subalpine communities in Glacier Bay National Park are dominated by alder thickets and salmonberry. Other species such as devil's club and copper flower may be locally important. The subalpine zone in Glacier Bay National Park and Preserve is very narrow. Some extensive areas exist but are more a function of natural disturbance by avalanche than climatic altitudinal zonation.	Subalpine vegetation in the Alsek and Tatshenshini Valleys exists on high valley slopes and mountains between roughly 1100 m and 1500 m. These areas are comprised mainly of medium to tall willow and alder shrub communities that become increasingly wet in lower portions of the watershed. Moist open areas are also common in these lower reaches. Alpine and subalpine vegetation in the Chilkat River drainage occurs on low mountain slopes. These areas consist of dense, lush growths of tall willows, alder and birch.

Table 5.2 (cont.): Basic Vegetation Characteristics of the St. Elias Mountain Parks

Typical Alpine Zone Communities			
Kluane NP(1)	**WRST NPR(2)**	**GLBA NPR(3)**	**TAT-Alsek PP(4)**
Alpine areas in Kluane occur above an elevation of approximately 1400 m. The lower part of the zone is dominated by a low shrub willow-birch-krummholz mosaic up to 1m high. Ericaceous shrubs are more common in the park's southern areas. The communities extend to elevations of approximately 1600 m and could be classified as either high subalpine or low alpine areas. The upper alpine zone occurs above 1600 m and is characterized as dry alpine tundra. These areas are dominated by matted alpine plants such as Dryas and a variety of dwarfed vascular plants.	Alpine areas may extend as low as 3,000'. Dry alpine communities (alpine tundra) consist mostly of low, matted alpine plants dominated by mountain avens and are found on the steeper mountain slopes and exposed ridges. Moist alpine communities (alpine meadows) consist of sedges (*Carex* sp.) and grasses interspersed with low willow (*Salix* sp.) and birch (*Betula* sp.) shrubs. These community types occur mostly on more gradual slopes and are quite lush in coastal areas. Alpine barrens characterized by crustose lichens dominate the high altitude areas not covered by perpetual ice.	Alpine communities are found at most elevations above 2,500'. Communities extending up to 6000' can be quite lush, forming a complex mosaic of alpine heaths and meadows. Species diversity in these mosaics is high. More common examples include deer cabbage, mountain heath, crowberry, mosses, and various sedges and avens. Alpine barrens dominate areas above 6000'.	Alpine areas in the drier central portions of the park extend from roughly 1500 m to 1700 m and are comprised of a number of low growing willows, Dryas, festuca, and various lichens (i.e. alpine tundra). Alpine rock barrens are common throughout the portions of the park where glaciers dominate the landscape. Species composition of the alpine zone shifts in the wetter portions of the park where a coastal influence is more prominent. This includes the alpine areas of the Chilkat Pass, Klehini and Kelsall River drainages, and the Tarr Inlet area. Lush alpine heaths and meadows dominate much of these areas.

Sources: (1) Douglas, 1980; personal observations (2) Alaska Planning Group, 1975; NPS, 1986; Gallant *et al.*, 1995 (3) Streveler and Paige, 1971; NPS, 1984; personal observations (4) Peepre, 1992; BC MOF, 1992; personal observations.

presence or absence of a species was the only information which was truly universal across all information sources. Specific methods used in creating the lists are also described in the Appendix.

In addition to the mammal and bird species lists, a list of vascular plant species from each of the St. Elias Mountain Parks was also developed. However, due to a lack of botanical expertise on the part of this author the taxonomy on the list was not standardized and it remains in a raw format. Nevertheless, in conjunction with the other two lists, the vascular plant list is useful in providing insight into the biogeography of the St. Elias region.

Based on the data tabulated in the two species lists in Appendix E, the four St. Elias Mountain Parks and the Tetlin NWR combine to protect a total of 179 species of breeding birds and 55 species of terrestrial mammals. Table 5.3a summarizes the number of species protected in each area while Table 5.3b summarizes the number of species shared amongst the protected areas.

Despite some significant differences in species richness, the number of species in each park is not necessarily a reflection of the size of an area or its habitat diversity. For example, the lower number of species in the Tatshenshini-Alsek is likely also a function of the recent establishment of this park and the fact that biodiversity inventories and exploration have been limited in comparison to the other areas. Conversely, the lower number of species - particularly mammals - recorded in Glacier Bay National Park is no doubt related to the fact that this entire area was entirely under glacier ice until just over 200 years ago. It is evident upon examination of the species lists that recolonization of the

Table 5.3a: Species Richness in the St. Elias Mountain Parks

Park	Area	Total Number of Species Known to Occur	
		Breeding Birds*	Mammals*
Kluane National Park	22013	131	48
Wrangell St. Elias National Park	53420	143	40
Glacier Bay National Park	13355	108	29
Tatshenshini-Alsek Wilderness Park	9580	130	30
Tetlin National Wildlife Refuge	3739	119	49
Total	102107	179	55

*Breeding Birds refers to confirmed, probable, and possible breeders; Mammals refers to terrestrial mammals only.

Table 5.3b: Species Common to and/or Shared Between Protected Areas

Unique Species ➘	***KNP***	***WRST***	***GLBA***	***TAT***	***Tetlin***
KNP	2 Mammals 1 Birds	37 Mammals 118 Birds	29 Mammals 78 Birds	30 Mammals 117 Birds	42 Mammals 107 Birds
WRST	37 Mammals 118 Birds	0 Mammals 4 Birds	25 Mammals 95 Birds	26 Mammals 114 Birds	40 Mammals 109 Birds
GLBA	29 Mammals 78 Birds	25 Mammals 95 Birds	0 Mammals 10 Birds	22 Mammals 82 Birds	27 Mammals 68 Birds
TAT	30 Mammals 117 Birds	26 Mammals 114 Birds	22 Mammals 82 Birds	0 Mammals 3 Birds	27 Mammals 110 Birds
Tetlin	42 Mammals 107 Birds	40 Mammals 109 Birds	27 Mammals 68 Birds	27 Mammals 110 Birds	4 Mammals 5 Birds

* “Birds” refers to confirmed, probable, and possible breeders; “Mammals” refers to terrestrial mammals

area by more mobile species has occurred while less mobile species have yet to be recorded in the area.

Despite the variance in accuracy amongst park-specific species data, the actual number of terrestrial mammals as well as breeding birds in the St. Elias Region exceeds previously reported values modelled on continental patterns of species diversity. For example, an examination of maps contained in Brown and Lomolino (1998) indicates that the St. Elias region should support between 120 and 150 breeding birds, while the number of mammals it supports should be in the range of 40 to 50 species. Using these two estimates as guidelines, it appears that the St. Elias Mountain Parks support roughly 10 to 30 percent more species than expected.

5.6 WILDLIFE ECOLOGY

Because of the number of species present in the St. Elias region, the concept of indicator species was used in examining regional wildlife ecology. Large mammals were considered the most appropriate indicators because of their comparatively large home ranges, biophysical and sociobiological traits, and/or trophic positions. Furthermore, most of the systematic studies of wildlife in the region have focussed on this taxonomic group. Two major carnivores, grizzly bear and gray wolf, are described along with the region’s four major ungulates: moose, caribou, Dall sheep, and mountain goat. Information on each of these species was synthesized with a view to identifying and assessing similarities and differences in ecology throughout the St. Elias, continuity of distribution, and identifying areas of regionally important habitat by way of density estimates. The section concludes with a short discussion of some of the major threats faced by these species.

Black bears also inhabit the St. Elias region. However, their continental range is more extensive than that of the grizzly bear, their habitat requirements are less varied, and they are less threatened. As a result, there have been few studies of black bear ecology anywhere within the St. Elias region and, consequently, they are not included as one of the six regional indicator mammal species used here. Of note however, is the occurrence of the Glacier Bear. This is a steel-blue colour phase of the black bear whose global distribution is limited to the St. Elias region, specifically known only from the Tatshenshini-Alsek Wilderness, Yakutat and Malaspina Forelands, and the outer coast of Glacier Bay National Park (Herrero *et al.*, 1993).

Similarly, the wolverine is also distributed across most of the St. Elias region and individuals of this species are known to have extensive home ranges. However, there have been relatively few studies of the species undertaken in the greater St. Elias area and it was decided to forgo analysis of these studies in favour of other species for which more detailed information was available.

5.6.1 Wolf

The gray wolf *(Canis lupus)* is one of the most widely distributed terrestrial mammals in the world. However, persecution and habitat destruction across its entire range have severely reduced its global population. With the exception of the state of Minnesota, the wolf is listed as endangered in the lower 48 states. Northern Canada and Alaska represent the remaining core of the species' once widespread distribution in North America.

Several studies of wolf ecology have been undertaken in the St. Elias region and monitoring by staff of various resources management agencies occurs intermittently depending on budgets and management issues. In combination these studies and monitoring provide the basis for the synthesis of wolf ecology presented here.

Taxonomy and Genetics

Based on the classification by Hall (1981), three of North America's 24 subspecies of gray wolves occur in the greater St. Elias region: *C.l. pambasileus*, *C.l. columbianus*, and *C.l. ligoni*. However, a more recent classification by Nowak (1996) takes a broader approach, suggesting that many of 24 subspecies previously identified are actually gradual variations within the species, rather than distinct geographically correlated populations (Person *et al.*, 1996). This broader classification is supported by the conclusions of recent genetic analyses by Kennedy *et al.* (1991) and Wayne *et al.* (1992) that suggest there is little genetic differentiation amongst wolf populations across the continent. The newer classification delineates North American gray wolves into five subspecies and places two, *C.l. nubilus* and *C.l. occidentalis*, within the greater St. Elias region. However, there appears to be a very real potential for a disjunct western population of *C.l. nubilis* which occupies the Alexander Archipelago of southeast Alaska to be designated as a distinct sixth North American subspecies, *C.l. ligoni* (Person *et al.*, 1996).

Wolf Ecology in the St. Elias

Wolves exist in a complex social relationship that is still not fully understood. Populations consist of packs occupying adjacent areas, although instances of overlap are frequent and seasonal aggregations of packs have been observed (Fuller, 1989). The size of these packs as well as the territories that they occupy is thought to be related primarily to the type, distribution, and availability of prey (Fuller, 1989).

In the greater St. Elias region the primary prey species for wolves are moose, caribou, and Dall Sheep. Additional prey species include snowshoe hare, beaver, mountain goat, and arctic ground squirrel (Sumanik, 1987; Gray, 1987; Gauthier and Theberge, 1985; Cottrell, 1975). Sitka black-tailed deer are the predominant prey species in the Alexander Archipelago and coastal southeast Alaska and may become more important in Glacier Bay as post-glacial succession continues and deer populations increase (Person *et al.*, 1996). As might be expected however, prey species and their importance vary significantly with locale. For example, Meiklejohn (1994) reports that seals constituted approximately one third of the diet of a pack of 11 wolves monitored during the summer of 1993 in Glacier Bay National Park and salmon appear to comprise a significant component of the diet of wolves inhabiting coastal areas as well as the lower Copper River watershed in Wrangell-St. Elias National Park and Preserve (Mitchell and Barten, pers. comm., 1997).

As summarized in Table 5.4, studies from the St. Elias region and adjacent areas support the hypothesis that pack size and territory is determined largely by prey type and availability. For example, Sumanik's (1987) study of wolf ecology in the Kluane Wildlife Sanctuary found that territories were relatively stable where wolves fed largely on moose and caribou, while territories were less traditional and more variable where Dall sheep

Table 5.4: Summary Data from Wolf Studies Conducted in and near the Greater St. Elias Region

Source	Location	Mean Home Range (range)	Mean Pack Size (range)	Sample Size	Calculated Density	Primary Prey Species
Smith *et al.*, 1987(3)*	Southeast Alaska (Revillagigedo Island)	279 km^2 (79 to 447)	5.4 (2 to 12)	7 packs	25.7 per 1000 km^2	Black-Tailed Deer, Salmon, Beaver
Person *et al.*, 1996	Southeast Alaska (Prince of Wales and Kosciusko Islands)	280 km^2 (101 to 419)	7-9 (2 to 12)	8 packs	39 per 1000 km^2	Black-Tailed Deer
Hayes *et al.*, 1991(1)*	South-central Yukon	630 ± 120 km^2	8.6 (4 to 15)	10 packs	12.4 per 1000 km^2	Moose
Sumanik, 1987*	Kluane WS and Kluane NPR	754 km^2 (350 to 1757)	4.0 (2 to 8)	8 packs	6.7 per 1000 km^2	Dall Sheep, Moose, Caribou
Parks Canada, 1996 (Skjonsberg) (2)*	Kluane NP and Tat-Alsek	1028 km^2 (400 to 1600)	6.3 (2 to 14)	6 packs	6.1 per 1000 km^2	Moose, Dall sheep
FWS, 1990(2)	Tetlin NWR	848.5 km^2 (580 to 1104)	5.8 (2 to 12)	6 packs	6.8 per 1000 km^2	Moose, Caribou
Ballard *et al.*, 1981(4)	Copper River Basin, AK	1390 km^2 (691 to 2738)	6.9 (2 to 20)(3)	14 packs	7.7 per 1000 km^2	Moose, Caribou
Quinby, 1977 (cited in Hicks, 1994)	Yakutat Forelands	NA	6 (3 to 9)	6 packs	25.7 per 1000 km^2	Moose, Salmon, Black-Tailed Deer, Goat
BC MOE, 1983	Atlin Area	NA	7 (6 to 8 est.)	13 packs	7.0 per 1000 km^2	Moose, Caribou

(*) Radio collars were utilized in these studies. (1) The study by Hayes *et al.* (1991) monitored an exploited wolf population. Data obtained at beginning of wolf "control" (1983) is presented here. (2) Data from recent monitoring by Parks Canada and the US Fish and Wildlife Service has not been systematically analysed. Analysis was undertaken by the author. Data presented here is preliminary and pack ranges and densities are based on estimates derived through the regional GIS. (3) Calculated by author. (4) Ballard *et al.*'s population declined during the study, attributed to hunting and trapping. The density given here is a calculated mean of five fall population estimates that ranged from 6.6 to 10.3 wolves per 1000 km^2.

were the primary prey species. Furthermore, packs preying primarily on Dall sheep were smaller than those feeding on moose and caribou and exhibited a higher rate in the turnover of individuals. A five year study by Ballard *et al.* (1981) of wolves in the Copper River basin found an inverse relationship between the size of a wolf pack's territory and the density of moose populations. Studies from southeast Alaska (Person *et al.*, 1996; Smith *et al.*, 1987) clearly show that pack territories and size are significantly different due to the predominance of deer as a prey species and its high density populations.

Regional Distribution

For the most part, wolves are present throughout the greater St. Elias wherever suitable prey exist. This generally excludes the central icefields and valley glaciers but includes alpine and subalpine habitat often considered only marginal habitat for wolves elsewhere (Breneman, pers. comm., 1997). As shown in Table 5.4, home ranges for wolf packs are large. Dispersal of wolves can also be quite large. By adding capture-relocation data obtained from the Kluane wolf monitoring program to the regional GIS, dispersal of individual wolves in the St. Elias region and adjacent areas was calculated to exceed linear distances of 150 km.

Wolf packs in Kluane National Park are shared with the Kluane Wildlife Sanctuary, the Tatshenshini-Alsek Provincial Park, and unprotected lands in the Yukon. At present, Kluane National Park is known to occupy at least a portion of the range of seven packs (approximately 50 wolves) and at least three packs are known from the Tatshenshini-Alsek (approximately 15-25 wolves) (Skjonsberg, 1996 and 1997). The extent of shared wolves between Kluane National Park and Wrangell-St. Elias National Park and Preserve is unknown. However, Sumanik's study (1987) identified at least one pack comprised of eight individuals whose territory fell within both the Kluane Wildlife Sanctuary and Wrangell-St. Elias NPP.

During 1990, at least eight packs were known to range within the Tetlin NWR (FWS, 1990). Four of these packs (approximately 35-40 wolves) were shared with Wrangell-St. Elias and three (8-12 wolves) were shared with unprotected lands in Yukon. Not one pack had a range entirely within the refuge. While monitoring of wolves has been sparse in Wrangell-St. Elias, park biologist Carl Mitchell (pers. comm., 1997) estimates a population of approximately 100 wolves from the north-central portions of the park (i.e. Wrangell Mountains) that is partially shared with unprotected areas in the Copper River Basin. Hicks (1994) estimates the number of packs in this area to range between 8 and 13 and reports a tendency for these wolves to "travel the larger rivers flowing out of the steep mountains as a route to higher elevations to hunt sheep (and to) use lower elevation riparian areas to hunt moose" (pg. 49). She notes that this contrasts with lowland areas to the west where moose densities are much higher.

While wolves were known from the Yakutat area prior to the immigration of moose in the 1930s, their numbers appear to have increased as a result of the new source of prey and now number approximately 50 individuals (Hicks, 1994). West of Yakutat Bay on the Malaspina Forelands, Hicks (1994) cites an estimate of 12 wolves in 2 packs for the early 1980s. Approximately 70 wolves in 10 packs are thought to inhabit Alaska GMU 1-C, which includes Glacier Bay, but no quantifiable estimates exist for the park.

5.6.2 Grizzly Bear

Like the wolf, the grizzly or brown bear *(Ursus arctos)* was once distributed widely across the northern hemisphere, but hunting and habitat destruction has reduced this distribution to small isolated populations in most of its former range. In the United States the grizzly bear is listed under the Endangered Species Act as threatened outside of Alaska and now occupies only 1% of its former range in this area (Waits *et al.*, 1998). In Canada the grizzly is considered vulnerable throughout much of its range in Alberta and British Columbia (Banci *et al.*, 1994). The Yukon and Alaska represent the last remaining stronghold of the species' former North American range.

Grizzly bears are often used as both umbrella and indicator species because of their requirement for large wilderness areas (Mattson *et al.*, 1996) This, combined with their current status and life history characteristics have contributed to the fact that it is a much studied species across North America, and the St. Elias region is no exception. The most extensive grizzly monitoring and research is carried out in Kluane National Park where in addition to annual monitoring and periodic surveys, an intensive 5 year study of more than 50 radio collared individuals has just been completed in collaboration with the University of British Columbia. Extensive monitoring of grizzlies in Wrangell-St. Elias and Glacier Bay has not been carried out, but data from studies in adjacent areas is available.

Taxonomy and Genetics

A recent study by Waits *et al.* (1998) analysed mitochondrial DNA from 317 grizzly bears across North America. Their results identified four distinct genetic clades across the continent: (i) a group limited only to bears inhabiting Admiralty, Baranof, and Chichagof islands in southeast Alaska; (ii) a group including bears from throughout mainland Alaska and Kodiak Island; (iii) a group including populations from Yukon, Northwest Territories, Northern British Columbia, and extreme eastern Alaska - including the coast south of Wrangell-St. Elias National Park; and, (iv) a group containing individuals from southern British Columbia, southern Alberta, Idaho, Montana, and Wyoming. Some overlap between clades ii and iii occurred in the Arctic National Wildlife Refuge of Alaska.

Given that grizzly bears are highly mobile and can disperse hundreds of kilometres (see below), the existence of a phylogeographic structure in North American grizzly bears is somewhat surprising, and contrasts with those studies of the gray wolf noted above. Waits *et al.* proposed three primary reasons for this difference: “(i) separation and genetic divergence of brown bear populations in glacial refugia during climatic fluctuations of the Pleistocene, (ii) multiple migrations of brown bears into North America from Asia, and (iii) low levels of female dispersal” (pg. 413).

A sister study (Paetkau *et al.*, 1998) assessed genetic diversity in North American grizzly bears by analysing 683 tissue samples from 12 bear populations distributed across the continent - including Kluane National Park. Sample analysis revealed two notable results with respect to the greater St. Elias region: (i) the Kluane population expressed the highest level of genetic diversity, and (ii) the main factor affecting genetic diversity appeared to be connectedness to other intact populations. In combination, these results appear to indicate that one of the primary reasons for the Kluane population’s genetic diversity is its connectedness - and therefore capacity for genetic exchange - with surrounding populations. Moreover, it indicates that this connectedness must be maintained in order to sustain the genetic diversity - and thus evolutionary adaptability - of this population.

Grizzly Bear Ecology in the St. Elias

Grizzly bears are opportunistic omnivores, and the type and relative proportion of foods in their diet varies significantly with locale and time of year. The availability of food also plays a significant role in the annual cycle of bear activity, including factors such as timing of hibernation, and in the size of individuals (LeFranc *et al.*, 1987). Pearson (1975) found that grizzlies inhabiting the Kluane Wildlife Sanctuary and eastern portions of the National Park emerged from hillside dens in late April and early May and began to feed primarily on the roots of *Hedysarum alpinum* in snowfree areas. Subsequent distribution throughout the year was influenced heavily by plant food availability, including horsetail *(Equsetum arvense)*, cow parsnip *(Heracleaum lanatum)*, and - most importantly - soapberries *(Shepherdia canadensis)*. Arctic ground squirrels *(Spermophilus undulatus)* comprised a large portion of the meat protein consumed, particularly during early fall before the return to den sites in mid-late October. Other prey species including moose, caribou, Dall sheep, and mountain goat are also known to be regular dietary components of grizzly bears in the interior areas of the St. Elias region (Gauthier and Larsen, 1986 ; Ballard, Spraker, and Taylor, 1981; Hoefs and McTaggart-Cowan, 1979; Gray, 1987).

Significant differences exist, however, between interior grizzly bears and grizzly bears inhabiting coastal areas. Coastal grizzlies are typically larger than their interior cousins. Yet the assertions of Rausch (1963) that these differences are not genetically related are confirmed by the recent genetic analyses noted above. Instead, these differences can be attributed to diet, as coastal bears have access to large quantities of salmon and therefore diets rich in protein.

Similar to research and monitoring undertaken elsewhere, studies carried out in the greater St. Elias region demonstrate that the home ranges of grizzlies can be quite large and that many bears, especially females, show a strong fidelity to home ranges from year to year (Johnston *et al.*, 1985). Furthermore, male grizzlies exhibit substantially larger home ranges than females, particularly females with young of the year (YOTY) which normally have the smallest home ranges. Such trends are summarized in Table 5.5. Subadult males may occupy portions of their mother's home range as they approach sexual maturity, but are much more likely to range widely and extend travel beyond maternal home range. Most often, these are the individuals in which long distance dispersal is observed.

It is important to note however, that home range sizes can vary widely between ecosystems (LeFranc *et al.*, 1987). Craighead and Mitchell (1982) conceptualized grizzly bear populations into two broad types: those existing in ecosystems with concentrated food sources and those without food concentrations. Where food concentrations occur, grizzlies are more likely to have smaller home ranges and/or more frequently overlapping home ranges. This is well illustrated in the St. Elias region where coastal bears having regular access to salmon have much smaller home ranges than their interior counterparts (Schoen *et al.*, 1983). Furthermore, it is also important to note that the lifetime home

Table 5.5: Spatial-Ecological Data from Grizzly Bear Studies Conducted in and near the Greater St. Elias Region

Study	Location	Mean Annual Home Range	Sample Size	Calculated Density
Schoen *et al.*, 1983	Admiralty Island	> 153 km^2(adult♂) > 21 km^2(adult ♀) > 89 km^2(subadult♂) > 7 km^2(subadult♀)	18	1 per 10-20 km^2 (est.)
Pearson, 1975	Kluane NP and WS	>287 km^2(adult♂) >86 km^2(adult ♀) >70 km^2(subadult♂) >88 km^2(subadult♀)	53	1 per 27.2 km^2
McCann, 1997	Kluane NP and WS	>1142 km^2 (adult♂) >124 km^2 (adult ♀) >837 km^2 (subadult♂) >143 km^2 (subadult♀)	60	NA
Simpson, 1992 (1)	Tatshenshini-Alsek PP	NA	NA	1 per 23-28 km^2 (est.)
Larsen and Markel, 1989	Southwest Yukon (excl. Kluane NP and WS)	>1169 km^2 (adult ♂) >279 km^2 (adult ♀) >357 km^2 (subadult ♂) >189 km^2 (subadult ♀)	27	1 per 62.5 km^2
Campbell, 1985	Copper River Delta, AK	>295 km^2 (adult ♂) >174 km^2 (adult ♀) >316 km^2 (subadult ♂) >203 km^2 (subadult ♀)	9	1 per 14-16.3 km2
Miller and Ballard, 1982	Nelchina/Upper Susitna Basins, AK	>850 km^2 (adult ♂) >415 km^2 (adult ♀) >848 km^2 (subadult ♂) >118 km^2 (subadult ♀)	15	1 per 41 km2
Miller, 1985; Miller *et al.*, 1986.	Susitna River Basin, AK	>1014 km^2 (adult ♂) >294 km^2 (adult ♀) >1218 km^2 (subadult ♂) >320 km^2 (subadult ♀)	56	1 per 35.8 km2

(1) Cited in Herrero *et al.*, 1993
NA - Data not available

range of a grizzly may be significantly larger than its seasonal or annual home range, depending on factors such as food availability, breeding activity, and den site availability (LeFranc *et al.*, 1987). As such, recorded home ranges should be considered as minimum values when utilizing them for management purposes.

Regional Distribution

With the exception of the interior icefields and valley glaciers, grizzly bears can be found throughout the entire St. Elias region. As presented in Table 5.5, densities have been recorded as high as 1 per 14 km^2 in the Copper River Delta area, although densities of 1 per 25-30 km^2 are more likely for the interior mountainous areas, with still lower densities in adjacent plateaus.

Identifying key habitat for grizzly bears is difficult because of the species' utilization of a wide variety of habitats. Moreover, at a continental level, much of the entire St. Elias region outside the icefields could be considered significant habitat for the species. Nevertheless, several efforts have identified key habitat in areas throughout the St. Elias region. These are illustrated in Figure 5.9. Although these key habitat areas were defined differently by the various sources, they illustrate the "circumregional" distribution of key grizzly bear habitat.

Each of the protected areas in the St. Elias region harbours grizzly bears, and populations in each are considered to be stable. However, because of the large home ranges of bears, each park shares its grizzly population with at least two other jurisdictions. Recent radio and satellite telemetry monitoring of bears in Kluane National

FIGURE 5.9 - KEY GRIZZLY BEAR HABITAT

(Located In Map Folio)

Park indicates that approximately 40% of collared bears are transboundary with the Tatshenshini-Alsek Wilderness, Kluane Wildlife Sanctuary, and unprotected Yukon lands (Breneman, pers. comm., 1997). The extent of transboundary movements between Kluane NPR and Wrangell-St. Elias NPP is likely minimal but regular movements between Wrangell-St. Elias, Tetlin NWR, and Kluane WS are likely (Doyle, pers. comm., 1997; Mitchell, pers. comm., 1997; Theberge, *et al.*, 1986).

While there have been no systematic studies of grizzly bears undertaken in Wrangell-St. Elias, it is believed that the population density is relatively high, especially in the lower reaches of the Copper River watershed where populations have access to extensive salmon runs (Mitchell, pers. comm., 1997). Consistent with the differentiation between coastal and interior grizzlies, male bears in this area appear to reach weights of 270 to 320 kg (600 to 700 lbs) (Mitchell, pers. comm., 1997), almost twice the average weight known for male bears in the southwest Yukon (Pearson, 1975). Bears in the northern portions of Wrangell-St. Elias are likely to be more comparable in size to the population recorded by Miller and Ballard (1982) in the Nelchina basin of Alaska, where adult males averaged 198 kg (Mitchell, pers. comm., 1997).

Grizzly bears are known to inhabit the Yakutat forelands and the Glacier Bay outer coast. While the size and density of this population is unknown, it is known that movement of this population into the Alsek River corridor does occur (Yerxa, pers. comm., 1997). Moreover, it is known that much of the vegetated portion of the Tatshenshini-Alsek Wilderness - particularly the river valleys - is high quality bear habitat (Herrero *et al.*, 1993), suggesting that movements both up and down the Alsek corridor may be extensive. Similarly, movement of individuals between Glacier Bay proper and a population inhabiting the Chilkat mountains and the west Lyn Canal coast is known to occur by way of the Endicott River valley (Yerxa, pers. comm., 1997).

5.6.3 Moose

Of the four recognized subspecies of moose (*Alces alces*) in North America, two are present in the greater St. Elias region. *A.a. gigas* is the largest subspecies of moose known and appears to have evolved during the Wisconsin ice age in the ice free area of north-central Yukon and Alaska. The other subspecies - *A.a. andersoni* - moved northwards with the retreat of the continental ice mass and reaches its northern limits in southern Yukon. The southwestern Yukon represents a transition zone between the ranges of the two subspecies (YDRR, 1997).

The moose is an important species from both a game and subsistence viewpoint throughout the St. Elias region as it is across much of its North American range. Given a common managerial objective of maintaining moose populations large enough to support a human harvest, population surveys are undertaken on a near-annual basis in several locations in both southwest Yukon and south-central Alaska. The result is a collectively extensive dataset encompassing a complete range of population parameters. Studies of moose ecology and life history in the St. Elias region are more sporadic but have been undertaken in areas where high densities are known to occur.

Habitat and Ecology

Moose may occupy a wide variety of habitats throughout the year. Willow (*Salix* sp.) is the preferred year-round forage of moose and individuals spend much of their time in habitats where willow is common. Wetlands are also used for their aquatic browse and may also be used by cows to provide protection and/or escape routes from predators during calving and the post-calving period (YDRR, 1997).

The most common habitat type used by moose in interior areas of the St. Elias region are "shrub habitats commonly associated with post-burns, lowland floodplains, and climax subalpine communities" (Wattereus *et al.* 1989: 18-19). In fact, moose in the interior areas of the greater St. Elias region are often found throughout the subalpine, which is quite different from moose in more southern areas of North America, and even moose in the coastal areas of the St. Elias (Mitchell, pers. comm., 1997). The reason for this use of higher elevations may be a function of terrain given the fact that wetlands, and therefore aquatic browse, are less common in the mountainous interior.

The subalpine also acts as important rutting habitat in the St. Elias. Individuals from the Tetlin-Northway flats in and around the Tetlin NWR are known to migrate to the Mentasta and Nutzotin Mountains during the fall rut (Doyle, 1989), and late autumn surveys reported by Larsen (1982) and Johnston *et al.* (1984) indicate that the majority of the moose population of the southwest Yukon is at or above treeline during this time. Winter habitat use seems to depend on weather severity. In areas of heavy snowfall moose will often move to forested lower elevations as winter progresses to gain access to better browse and avoid deep snows (Waterreus *et al.*, 1989). This movement is less pronounced in areas where snow accumulation is less significant.

In southeast Alaska and along coastal plains such as the Yakutat and Malaspina forelands, moose habitat is associated primarily with riparian areas and post-glacial early successional vegetation (USFS, 1997).

Regional Distribution

Knowledge gained through the numerous population surveys as well as habitat studies undertaken through capture-relocation analysis in the southwestern Yukon and the interior of south-central Alaska suggests that any terrain below 4500' with some riparian area and/or willow browse can be considered potential moose habitat (Mitchell, pers. comm., 1997). Despite this broad distribution much of the potential habitat is rather marginal and moose densities are actually low when compared to other North American regions. As illustrated in Figure 5.10, densities in the more mountainous areas of this region average only 0.15 moose per km^2. Given these low densities across a broad range, there has been some emphasis on identifying key habitat where moose concentrations occur. These areas, identified in Figure 5.10, are centred mostly on subalpine areas and heavily forested riparian valleys.

Moose populations exhibit a more patchy distribution in coastal areas of the St. Elias region when examined at the regional scale. In fact, the range of moose in the St. Elias region has come to include coastal areas only in the last century. Moose were introduced into the Copper River Delta area in 1949 and have flourished since. Densities in this area are amongst the highest in Alaska (MacCracken, 1992). A phenomenal natural

FIGURE 5.10 - MOOSE DENSITY AND KEY HABITAT

(Located In Map Folio)

expansion of moose range has occurred in the last 70 years in southern portions of the St. Elias region and into southeast Alaska. The expansion occurred as a result of moose migration down the Alsek and Tatshenshini and Stikine river corridors and subsequent dispersal along coastal areas. Moose were first reported at Yakutat between 1930 and 1932. With the exception of a moose population at Berner's Bay which was introduced by humans in the mid 1960s, all moose in southeast Alaska have resulted from these natural migrations (USFS, 1997). The population of moose now inhabiting Glacier Bay has grown from a progressive migration of individuals from the Lynn Canal across the Chilkat Range by way of the Endicott River corridor (Yerxa, pers. comm., 1997).

Transboundary movement of moose in and out of the region's protected areas is known to occur regularly and is particularly frequent along the eastern boundary of Kluane National Park and the western boundary of Wrangell-St. Elias as moose move to and from late winter concentrations located at low elevations outside the parks (Breneman, pers. comm., 1997; Mitchell, pers. comm., 1997). Movement of moose between protected areas also occurs, with regular exchange of individuals between Wrangell-St. Elias NPP and Tetlin NWR as well as between Kluane NPR, Kluane WS, and the Tatshenshini-Alsek Wilderness. Given the location of fall and winter concentrations along the White River, direct exchange between Wrangell-St. Elias and Kluane WS undoubtedly occurs. However, poor moose habitat likely prohibits a direct exchange between Kluane NP and Wrangell-St. Elias.

5.6.4 Caribou

Two major subspecies of caribou, barren-ground caribou (*Rangifer tarandus granti*) and woodland caribou (*Rangifer tarandus caribou*), occur within the greater St. Elias region. While they do exhibit slight physical differences, variations in behaviour and habitat constitute the primary differentiation between the two subspecies. Barren-ground caribou generally form large herds and migrate substantial distances between traditional spring calving grounds and winter ranges. During the summer post-calving period barren-ground caribou aggregate into large groups. Conversely, woodland caribou form smaller groups ranging over smaller areas. They disperse widely during calving, but aggregate during the rut and winter. Migration tends to be primarily altitudinal in nature, with alpine areas acting as summer habitat and forested valleys providing winter habitat (Waterreus *et al.*, 1989).

Herd Distribution and Status

Inventory and monitoring of caribou populations is the most intensive and extensive for any species of large mammal in Alaska and the Yukon. This is primarily due to the nature of the caribou as an important subsistence and game species and the sociobiologic characteristics of the species. Although herd ranges may overlap, and some egress and ingress of individuals occurs between herds, both barren-ground and woodland caribou exhibit a high level of herd fidelity and herds typically utilize the same key habitat such as calving grounds, rutting and wintering areas, and migration corridors on an annual basis (Farnell, pers. comm., 1997).

Figure 5.11 presents range and key habitat of the six caribou herds that range within and/or immediately adjacent to the greater St. Elias region as well as those of three other nearby herds. The supplement to the map summarizes characteristics of each herd. Particularly evident from the map is the overlapping winter range of the Nelchina, Mentasta, and to a lesser extent, Chisana herds. Despite separate calving and summering areas, these herds often intermix during the winter and cross into several different jurisdictions. Movements in and out of Wrangell-St. Elias NPP and Tetlin NWR in Alaska are frequent and the combined winter herd often moves into Yukon.

Also evident from the map is the absence of caribou from southern portions of the St. Elias region. While the Burwash/Kluane herd may utilize the extreme northern portions of Kluane National Park, caribou are entirely absent from Tatshenshini-Alsek Wilderness Provincial Park. The Ibex caribou herd to the east represents the nearest existing herd to the Tatshenshini-Alsek Wilderness. Of note however is evidence by way of traditional knowledge, historical records, and cast antlers that caribou were regular inhabitants of the southern portions of Kluane National Park and northeastern portions of Tatshenshini-Alsek Wilderness Provincial Park in the past (Lofroth and Mahon, 1993). Hoefs (1973) attributes the decline and eventual disappearance of this herd to “massive slaughter” by army personnel during construction of the Haines Road.

Historical population data for each caribou herd is presented in Figures 5.12 and 5.13. Examination of the two figures reveals several distinct trends. First, it is evident that the six caribou herds for which data is presented have fluctuated greatly in the past quarter century. The two barren-ground herds appear to have simultaneously undergone a

FIGURE 5.11 - CARIBOU HERD RANGES AND KEY HABITAT

(Located In Map Folio)

Supplement to Figure 5.11 (Caribou Range and Key Habitat)

Nelchina Herd
The Nelchina caribou herd is a barren-ground herd that ranges in east central Alaska and occasionally into the western Yukon. The Tetlin NWR and Wrangell-St. Elias NPP are the two protected areas relevant to this herd in the St. Elias Region. The Nelchina herd seems to experience periodic population eruptions every three or four decades, and currently appears to be at a high spot in this cycle (Farnell, pers. comm., 1997). The reason(s) for these fluctuations are not entirely clear. Van Ballenberghe (1985) reviewed the history and population dynamics of the Nelchina herd between 1950 and 1981 and concluded that hunting and severe winters were the major causes of the herd's fluctuations during this period. In contrast, Bergerud and Ballard (1988) concluded that predation by wolves played the most important role in the herd's population dynamics. More recently, Eberhardt and Pitcher (1992) argued that food limitation associated with poor range conditions actually lowered recruitment rates during the population's most recent decline and proposed controlling the size of the herd to prevent a long-term decline.

Fortymile Herd
The Forty Mile caribou herd is a barren-ground herd that ranges in east central Alaska and extends into the western Yukon. Early in this century the Fortymile herd numbered over 500,000 individuals and ranged from Whitehorse to Fort Yukon north of Fairbanks - an area over 220,000 km^2 (Valkenburg *et al.*, 1994). However, by the early 1970s the herd had declined to a population of less than 5,000. Various reasons have been proposed for this population crash including overhunting (Urquhart and Farnell, 1986), winter range destruction by fire (Leopold and Darling, 1953) and food limitation and subsequent emigration (Skoog, 1968). Because of the dramatic reduction in numbers, the herd's range shrunk considerably and winter range in the Yukon was no longer used. However, intensive management - primarily through wolf population reduction and control as well as hunting restrictions - has resulted in a steadily increasing population which now numbers approximately 20,000, and the herd appears to be expanding into some of its former historical range (Farnell, pers. comm., 1997).

Mentasta Herd
The Mentasta woodland caribou herd is a small intermountain herd that summers on the western slopes of the Wrangell Mountains in Wrangell-St. Elias National Park and Preserve. In winter, the Mentasta herd often intermingles with the Chisana and Nelchina herds. The combined winter herd may cross state, native, private, and federal conservation unit boundaries, as well as the Alaska-Yukon border (Route *et al.*, 1995; Lieb *et al.*, 1994). Historically, the Mentasta herd exceeded 3,000 individuals. However, concern over the status of the herd and its long term viability has arisen in recent years as numbers have declined to a current low of approximately 600 individuals (Mitchell and Barten, pers. comm., 1997).

In response to this decline, the annual recreational hunt on Mentasta caribou was closed in 1989, the annual subsistence hunt on the herd was closed in 1992, and the US National Park Service, US Fish and Wildlife Service, and Alaska Department of Fish and Game collaborated to develop a management plan to assist the population in recovering to former levels.

Chisana Herd
The Chisana herd is a small group of woodland caribou that winters in the Yukon along the White River and summers in Wrangell-St. Elias National Park and Preserve. However, these movements are dispersed in nature, and not as clearly defined as in other woodland herds (NPS, 1988). The current population of the herd is approximately 700 individuals. In recent years the Chisana herd has had poor calf survival and low rates of pregnancy. Consequently, hunting of the herd has been stopped on both sides of the international border. Farnell (pers. comm., 1997) hypothesizes that these biological trends are due to diet and nutritional problems on the herd's range, and not necessarily because of overhunting or predation. There is some speculation that the Chisana herd is grazing heavily on mosses and evergreen shrubs, and

that lichens - a staple of caribou food - are low in their diet. An investigation to assess range conditions has recently been funded by the ADF&G (Lenart, 1996).

Burwash/Kluane Herd

The Burwash (aka Kluane) caribou herd is a small woodland herd that ranges entirely within the Yukon. The most current population estimate for the herd is roughly 170 individuals. The herd occupies two distinct seasonal home ranges, one in the Burwash Uplands of the Kluane Wildlife Sanctuary where it is protected from hunting, and the other in the Brooks Arm Plateau around Kluane Lake. Key rutting grounds and winter ranges occur within both areas. Radio collaring and monitoring by Gauthier *et al.* (1983) identified a major migration corridor between these two areas across the Shakwak Trench that is utilized by the herd. This study also indicated that individuals do not linger in the Shakwak Trench and identified two concentrated migration periods during the year: a movement from the Burwash uplands to the Brooks Arm plateau in the rut-to-winter period, and a reverse movement that occurred primarily in April and May.

Aishihik Herd

The Aishihik caribou herd is a woodland herd whose range occupies the Ruby Ranges and the Aishihik Lake Basin. The herd numbered over 1500 individuals in 1980 but underwent a steady decline over the following 10 years (Farnell *et al.*, 1996). Studies by biologists at the Yukon Department of Renewable Resources indicated that individuals were very healthy and it was concluded that diet or range conditions were not a factor in the herd's decline. In an effort to stop the herd's decline, licenced hunting was prohibited in 1990 and First Nation's hunting was discouraged. In addition, a wolf control program was initiated in 1993 to reduce predation on the herd. Since the implementation of this program, the herd has increased to a population of 1200. In fact, prior to wolf control, the sex ratio of the Aishihik herd was less than 30 bulls for every 100 cows. Following wolf control this number rose to 50 bulls for every 100 cows.

With respect to range and key habitat areas, the winter range of the Aishihik herd is not as clearly defined as that of the other woodland herds due to annual variability in snow cover throughout its range as well as the fact that much of the area could act as viable winter habitat in various years (Farnell, pers. comm., 1997).

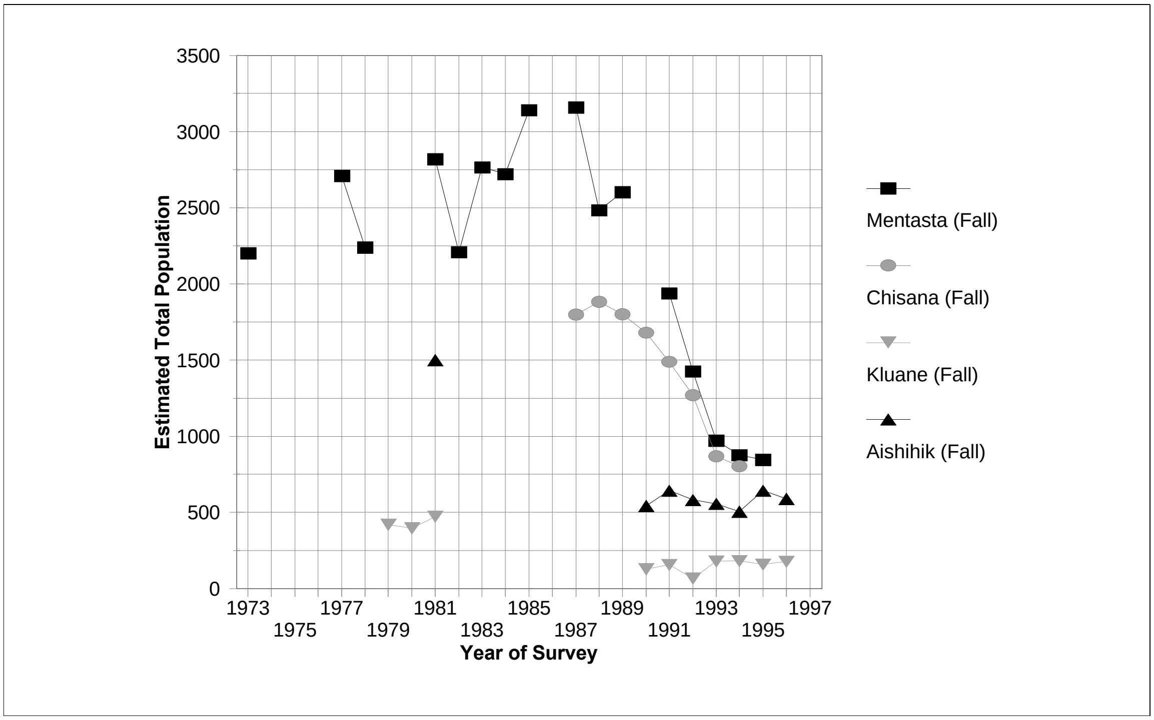


Figure 5.12 Woodland Caribou Population Estimates

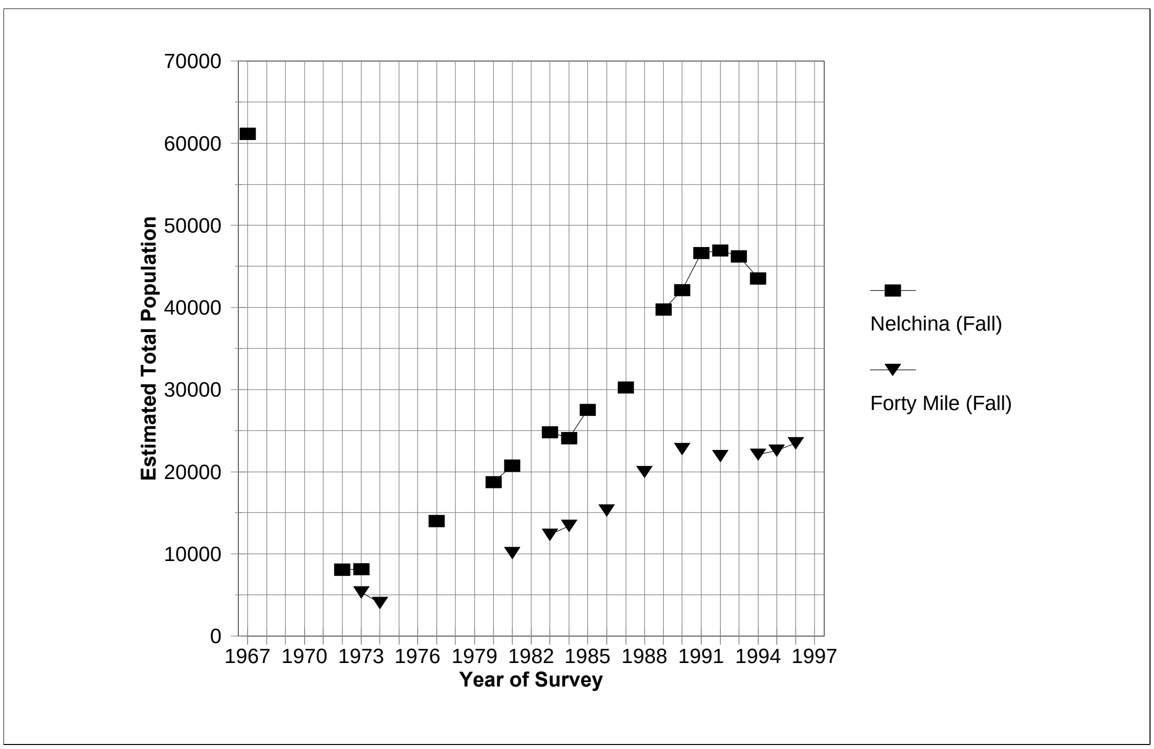


Figure 5.13 Barren-ground Caribou Population Estimates

(Source data obtained from survey results on file at Alaska Department of Fish and Game, Tok; US Fish and Wildlife Service, Tok; US National Park Service, Copper Centre; Yukon Department of Renewable Resources, Whitehorse) period of rapid population decline followed by a more gradual period of recovery. While data is sparse prior to the early 1980s, the four woodland caribou herds simultaneously experienced significant population declines in the late 1980s and early 1990s. Not surprisingly, calf:cow ratios from each herd support these trends in total population.

5.6.5 Dall Sheep

Of the two North American species of wild sheep, only the thinhorn sheep *(Ovis dalli)* occurs north of 60°N latitude. The Dall sheep *(O.d. dalli)* is the subspecies that occurs throughout the St. Elias region. It is distinguished from the stone sheep *(O.d. stonei)* by its distinctive white coat and slightly smaller size. The ranges of these two subspecies overlap in a small portion of the central Yukon where a subspecific intergrade, Fannin's Sheep, occurs.

Dall sheep carry no special status in the Yukon and Alaska, but are designated as vulnerable in British Columbia where the southern extent of the subspecies' range dips into the northern portions of the province. The significance of Dall sheep as a highly prized game species and the subsequent management considerations that this entails has resulted in regular inventory and monitoring of Dall sheep populations throughout its range. Furthermore, several landmark studies on the ecology of this subspecies have been undertaken within the St. Elias region, particularly those of Manfred Hoefs at Sheep Mountain in Kluane National Park. The result is that a good deal is known about the ecology of this species and its habitat requirements within the greater St. Elias.

Habitat and Ecology

Dall sheep are habitat specialists that range in alpine and subalpine areas feeding primarily on grasses and forbs. Surveys from locations throughout the greater St. Elias region consistently illustrate the species' preference for productive open meadow and grassland areas and an aversion to forested habitat. Shrub habitat in the subalpine zone may also be utilized. Studies at Sheep Mountain (Hoefs and McTaggart-Cowan, 1979; Hoefs *et al.*, 1975) determined that this population utilized 23 individual vegetation communities during the annual cycle and that five of these provided 90% of the population's total forage. Grasses and grass-like vegetation (eg. sedges) comprised 46% of all forage while forbs comprised 37%. Subalpine browse (primarily willows) comprised 16% and mosses and lichens less than 1%.

Populations of Dall sheep appear to be environmentally driven, as opposed to being controlled through predator-prey relationships. Weather and the effect that variables such as precipitation and snow cover have on vegetation growth and/or foraging ability is the driving force in short term population fluctuations (Geist, 1971). Dall sheep are migratory in the sense that they have predictable summer and winter ranges and migrate to and from these areas *via* predictable routes (Mitchell, pers. comm., 1997; Carey, pers. comm., 1997). Winter range is often located on steep south-facing slopes where strong winds deter significant snow accumulation (Hoefs and McTaggart-Cowan, 1979).

Dall sheep are a gregarious species that exist primarily in sex-based groups. Although mature rams may have frequent contact with ewes during winter when range is more restricted, the two really only mix during the rut in November and December. Ewes give birth in May and early June on cliffs which provide escape terrain from predators which, in the St. Elias region, includes primarily coyotes, golden eagles, and wolves but may also include wolverines, grizzly bears, and lynx (*Lynx lynx canadensis*) (Hoefs and McTaggart-Cowan, 1979). Nursery bands comprised of ewes, young rams and lambs form after the lambing period and remain together for the rest of the summer, largely separated from bands of mature rams. A radiotelemetry study by Durtsche *et al.* (1990) in the Tanana Hills of central Alaska assessed a population of 8 separate bands of ewes and 4 separate bands of rams and found that although some exchange of individuals did occur, bands were generally faithful to traditional independent ranges year after year.

Regional Distribution

Dall sheep are the most common large mammal of the St. Elias region. The total population for Wrangell-St. Elias NPP has been estimated at 25,000, with the majority of these individuals occupying areas north of the Chitina River (Strickland *et al.*, 1992). Populations in Kluane NPR and Kluane WS are estimated at 5000 (Hoefs and Barichello, 1985), and an estimate of 150 residents has been given for the Tatshenshini-Alsek Wilderness PP (Elliott, 1985). Additional numbers in surrounding unprotected areas may number as high as 5000 in the Yukon (Hoefs and Barichello, 1985) and 4000 in Alaska (Heimer, 1985). Given estimated populations of 70,000 for Alaska (Heimer, 1985), 19,000 for Yukon (Hoefs and Barichello, 1985), and 200 for British Columbia (Elliot, 1985) the greater St. Elias region appears to support roughly one third of the global Dall sheep population.

Figure 5.14 presents the distribution of Dall sheep in the greater St. Elias region. As illustrated on the map, sheep are present throughout much of the Wrangell Mountains and the Kluane Ranges, as well as portions of the Mentasta-Nutzotin and Chugach Mountains. With respect to protected areas, this includes the “green belt” of Kluane NPR, the Kluane WS, Wrangell-St. Elias NPP, as well as eastern portions of Tatshenshini-Alsek Wilderness PP and the extreme southwest corner of Tetlin NWR. Glacier Bay NPP does not support a population of Dall sheep.

Figure 5.14 also illustrates that Dall sheep populations are shared between the region’s protected areas and with adjacent unprotected areas. Populations straddle international and protected area boundaries and movement of sheep back and forth across these boundaries occurs regularly. However, because of their habitat specificity and short-distance migratory nature, these movements are more local in nature. Furthermore, landscape features such as the Shakwak Trench, Chitina Valley, and major icefields inhibit the exchange of individuals amongst populations.

Despite low rates of dispersal amongst populations, there have been observations of long distance dispersal by thinhorn sheep. Hoefs and McTaggart-Cowan (1979) report observation of a Fannin ram at the base of Sheep Mountain in Kluane NPR in 1973, a linear dispersal distance of 160 km from the nearest stone sheep population east of Lake Laberge and over 250 km from the nearest regular occurrence of the Fannin intergrade. They also report the successful hunt of a Stone ram between the White and Donjek Rivers, 200 km from the Lake Laberge population. Given these observations, and the “low

FIGURE 5.14 - DALL SHEEP RANGE AND SURVEYED DENSITIES

(Located In Map Folio)

probability of actually witnessing dispersal", they hypothesized that long distance dispersal amongst Dall sheep is actually "more important than is generally believed" (pg. 32).

Interpopulation Differences

Despite a widespread distribution in the St. Elias region, there are definite phenotypic differences between individual populations. Sheep in the Wrangell Mountains population, as well as those inhabiting the Logan nunatak area are generally larger in size and rams are known to have larger horns than in other areas (Mitchell, pers. comm., 1997; Winters, 1980). Moreover, the densities of sheep reported from the Kluane Ranges and Wrangell Mountains are amongst the highest known, yet their average life expectancy is below the species' average (Hoefs and McTaggart-Cowan, 1979).

Geist (1971) attributes genotypic differences amongst the mountain sheep of North America (*Ovis* sp.) to pressures of natural selection in recently deglaciated terrain:

> "When invading new habitat in the wake of glacial withdrawal, colonizing sheep would live in expanding, high quality populations due to superabundance of forage. In such populations rams grow large in body and horn size, interact intensely and frequently, but have short life expectancy. In high quality populations reproduction is heavy...(and) *high reproduction assures rapid replacement of dead large rams by equals*"(his emphasis) (pg. 340).

If Geist's hypothesis is extended to the population level, it would seem that the rationale for the phenotypic differences within the St. Elias region is the fact that these areas are only recently deglaciated in comparison to other portions of Dall sheep range, much of which occupies the Beringian refugium.

The application of Geist's hypothesis to individual populations is supported by

Winters (1980) who found a correlation between forage abundance and body and horn size in Dall sheep and reviewed observations by several authors who reported differences in both size and behavioural characteristics associated with forage abundance and range quality - particularly topographic variability.

5.6.6 Mountain Goat

The mountain goat *(Oreamnos americanus)* is distributed throughout the North American cordillera from Colorado to the Kenai Peninsula in Alaska (Chadwick, 1983). Given this distribution, the St. Elias region is actually at the northernmost extreme of its continental range. Unlike Dall sheep, many of the principal studies of mountain goat ecology have been carried out further south in core of the species' range. Nevertheless, important data and information has been collected on goat distribution throughout the St. Elias and some ecological investigations have been carried out.

Habitat and Ecology

Mountain Goats are sure-footed alpine habitat specialists that inhabit rugged mountainous terrain. Banfield (1974) describes them as preferring "steep, grassy talus slopes at the base of cliffs" but notes that they "also frequent small grassy ledges on the face of steep cliffs and rocky ridges, alpine meadows, and timberline" (pg. 409). Nannies and kids aggregate in the summer following kidding, which takes place in late May and early June. Billies tend to remain alone during this period at higher elevations, and join the nanny groups only during the late autumn rut (Banfield, 1974).

Mountain goats do not migrate in the traditional sense of the term. Rather, winter range occurs "as small pockets within the larger summer range and is comprised of precipitous south-facing slopes and cliffs and high ridge areas where sun and wind limit snow accumulation" (Gray, 1987, pg. 9:58). In addition, such terrain provides protection from predators (grizzly bears, wolves, coyotes, golden eagles, and wolverines) and reduces interspecific competition for forage resources. Summer range is considerably more extensive, although Rideout (1978; cited in Gray, 1987) suggests that north and east facing slopes are utilized more during this period as they tend to hold snow longer and, therefore, support lush snowbed vegetation.

In a four year habitat use study by C.A. Smith (1986) in southeast Alaska, goats were rarely observed on slopes less than 30 degrees or more than 400 metres away from cliffy terrain. In addition, over 85% of all winter relocations occurred in forested areas. This concurs with a previous study by Schoen and Kirchoff (1982) indicating that coastal old-growth forest provides important winter habitat for goats along the Alaska coast. The importance of forested areas as winter range for goats in interior habitats has not been assessed in the greater St. Elias region. However, in his review of mountain goat ecology, Chadwick (1983) states that "while goats in noncoastal environments may move down into the forest zone during the snow months, they usually remain high enough that the mountainside offers extensive open cliff faces between stands of trees" (pg. 49).

Using radiotelemetry, C.A. Smith (1986) determined an average home range of 11.7 km^2 for females and 44.9 km^2 for males in southeast coastal Alaska. Schoen and Kirchoff (1982) found no tendency towards migration in another goat population in southeast Alaska and distance between relocations of radio-collared individuals was relatively short, ranging from 3.2 km to 14.4 km and averaging 7 km. Annual home range fidelity was significantly stronger for females than males, particularly with respect to winter range. Again, however, similar studies have not been carried out in interior portions of the St. Elias region, although it is likely that differences do exist based on the noted differences in habitat use.

Regional Distribution

Like Dall sheep, mountain goat populations are controlled primarily through environmental conditions as opposed to predation. Weather and its effect on vegetation growth and/or foraging ability appears to be the driving force in population fluctuations (Chadwick, 1983). Because much of their time is spent grazing on high cliff edges and remote alpine terrain, this species is present generally only in areas where precipitation is abundant enough to support vegetation growth in this harsh habitat (Carey, pers. comm., 1997).

Figure 5.15 illustrates the approximate range of mountain goats in the greater St. Elias region. As illustrated on the map, each of the four national parks and equivalent reserves sustain a population of mountain goats. Transboundary populations also exist between some of these areas. Hoefs (1980) estimates that approximately 100 goats migrate periodically between extreme southwest Yukon and northern British Columbia as dictated by high altitude snow accumulation. Goat distribution is continuous between Tatshenshini-Alsek Wilderness and southeast Alaska, although the extent of transboundary

FIGURE 5.15 - MOUNTAIN GOAT RANGE AND SURVEYED DENSITIES

(Located In Map Folio)

movements are unknown. A population of goats inhabiting the Logan Nunatak in the Icefield Ranges is shared between Kluane and Wrangell-St. Elias National Parks, but appears to be largely isolated from other populations. Similarly, the Wrangell Mountains population is also isolated from other populations.

Figure 5.15 also illustrates the distributional limitations associated with range edge conditions. The highest densities of mountain goats occur in mountainous terrain where precipitation is highest. In the greater St. Elias this includes those areas influenced by moist pacific air: the southeast portions of Kluane National Park and Kluane Wildlife Sanctuary, the Chugach Mountains, the Haines Triangle, and - most notably - southeast Alaska. In fact, Fox (1984) estimated some populations on the outer coast of Glacier Bay National Park to exceed 4.0 individuals per square kilometre. Conversely, distribution is sporadic and populations occur at low densities in areas with little precipitation - notably the Wrangell Mountains and the northern portions of Kluane National Park. Hicks (1996) describes goats occurring in "substantial numbers" north of the Chitina River from the Lakina River to the Canadian border, but classifies the rest of the Wrangell Mountains as marginal goat habitat with densities "much lower than in areas with more favourable habitat" (pg. 130).

Klein (1965) surmised that mountain goats moved north and populated southern Alaska by way of coastal corridors following glacial retreat, rather than utilizing the interior-coast river corridors of the Stikine and Alsek Rivers. If this is true, their relation with populations inhabiting interior areas of the St. Elias region is likely not as direct as it is for moose. Unfortunately there is no information on long distance dispersals of goats in the greater St. Elias region from which an assessment of population linkages can be made, nor have any genetic analyses been carried out on these populations.

5.6.7 Population Stresses

Despite the fact that the St. Elias region is comprised mainly of protected areas, populations of each of the six species of large mammal examined here are subject to a number of stresses; human-induced and otherwise. Hunting - both sport and subsistence - is the most significant of these. With the exception of Glacier Bay National Park, it occurs in all areas of the region on each of the six species. Additional stresses include the multitude of direct and indirect affects associated with increasing human development such as habitat disturbance, loss, and fragmentation; increased vehicular traffic (auto, air, and boat); road building and/or improvements; and behavioural disturbances as a result of increased recreational use of habitat. A number of specific stresses - mostly direct causes of mortality - are discussed below.

One of the greatest stresses on the St. Elias wolf population is wolf "control". This generally refers to the prescribed killing of wolves, but may also include sterilization of alpha wolves, in an effort to facilitate growth of prey populations. Wolf control has a long history in the region. Historically it was carried out as part of widespread persecution of the species and as a means of maintaining high numbers of ungulates for game hunting. More recently however, it has been utilized as a method for reducing predatory pressures on ungulate populations that have undergone significant declines.

Recent wolf controls to have occurred in the greater St. Elias region include a program centred on the Aishihik Lake area to facilitate recovery of the Aishihik caribou herd as well as moose in that area. This program extended from 1993-1996 during which time more than 160 wolves were destroyed (Breneman, pers. comm., 1997). A sterilization program is currently being undertaken by the ADF&G to assist the Fortymile caribou herd recover to a population of 60,000 individuals (Farnell, pers. comm., 1997).

Caribou are subject to both sport and subsistence hunting and are hunted in unprotected and protected areas. The management of caribou hunting in both Alaska and Yukon uses the herd as the basic management unit. Independent limits are set for each herd based on its total population, recruitment, and calf:cow and bull:cow ratios. Despite the strategies used to determine the size of a hunt, caribou populations continue to undergo substantial fluctuations; a testimony to the multitude of factors which influence their numbers. As discussed in Section 5.6.4, significant hunting restrictions have been place on each of the Mentasta, Chisana, Aishihik, Kluane, and Forty-mile herds.

It is, perhaps, ironic that the very nature of caribou has the potential to work against the survival of individual populations. The fidelity of caribou to herd and habitat may act to render them more susceptible to extrinsic population stressors such as habitat change and alteration, hunting, and predation. In fact, because of their migratory nature, not one of the caribou herds relevant to the greater St. Elias region have ranges completely within a protected area. Moreover, historical evidence in other parts of North America demonstrates that when woodland caribou herds reach very low numbers, their chance of recolonizing former range is greatly reduced (Farnell, 1994).

Hunting and stochastic events appear to act as the main stressors on mountain goat and Dall sheep populations in the St. Elias region. Their relative habitat specificity in comparison to the other species discussed here renders them more susceptible to stochastic environmental events such as rapid habitat change. Furthermore, their gregarious nature - particularly that of Dall sheep - augments this susceptibility.

The hunting of Dall sheep has a long history in the St. Elias region. The potential loss of Dall sheep sport hunting in the Wrangell Mountains was one of the primary issues associated with the establishment of Wrangell-St. Elias National Park and, ultimately, contributed to the creation of the National Preserve designation where sport hunting would be permitted. As described by Wright (1984) harvest levels of Dall sheep were used to delineate National Preserve areas from National Park areas. Monitoring of Dall sheep populations and regulation of hunting remains one of the highest wildlife management priorities in the Park/Preserve today. In contrast to Dall sheep, the regulation and/or enforcement of mountain goat hunting is challenging because females are difficult to distinguish from males at a distance. As such, special management consideration for the female cohort, which is also more accessible to hunters due to summer range in aggregated groups, is difficult.

Hoefs (1974 & 1978; cited in Barichello and Carey, 1988) assessed goat range in Yukon Game Management Zone 7 (southwest Yukon) and believed it was capable of supporting a much higher population than what existed at the time but that the population had been severely reduced as a result of overhunting in the area. Subsequent to this assessment, hunting was progressively restricted over the next ten years to the point where all hunting was closed. Surveys by DRR biologists in this region from 1973 to 1987 indicated a population growth rate of 12.7%, suggesting that the hunting restrictions were assisting the population in recovering. However, Barichello and Carey (1988) caution that the low populations may have been caused by severe winters and then exacerbated by hunting pressures.

The US Forest service uses mountain goats as a management indicator species for the Tongass National Forest because of its habitat specificity. In their 1997 land management plan, the Forest Service states that the potential exists for the species to be overhunted in southeast Alaska if road access is improved. Because of an apparent relationship between mountain goats and old growth forest as winter habitat, Hicks (1996) states that there is "potential for clearcut logging to negatively affect populations through removal of old-growth timber and improved human access. Logging roads can result in increased legal harvest, illegal harvest, and disturbance" (pg. 55). An example of this is given for the area near Icy Bay, just outside Wrangell-St. Elias NPP boundaries, where goat numbers have declined considerably since clearcutting on state and native lands began in the area (Hicks, 1996).

No other species has gained as much attention in evaluating the direct and indirect impacts of human activities on wilderness and wildlife in western North America as the grizzly bear. A substantial amount of research has been undertaken in the northern US and southern Canadian Rockies on this topic (see Mattson *et al.*, 1996 for a review) with the general conclusion that bear mortality is positively correlated with road density and nearness to human facilities and that large relatively unmodified blocks of habitat are necessary to sustain a grizzly population. While this suggests that populations in the St.

Elias region are far more secure than their southern counterparts (i.e. because of their larger, more continuous nature and the low human population in the region) stresses on these populations still remain.

Grizzly bears are less susceptible to environmental stochasticity than the ungulates mentioned above because of their solitary nature and use of several different habitat types. However, they are in many ways more susceptible to human-induced population stresses, particularly because their low reproductive rate inhibits mortality replacement and recolonization of habitat. Human-caused mortality of grizzly bears is the most evident of these and occurs primarily by way of sport hunting. Incidents of “defence of life and property” and the shooting of “problem” bears also occur, although on a far less frequent basis. Given the fact that research has shown that grizzlies are the primary predators of moose calves in the southwest Yukon and southcentral Alaska, a debate over whether or not to implement grizzly bear control (in the same fashion as the wolf control discussed above) has arisen in recent years and remains a potential future population stress (Barichello, 1996; Chambers, pers. comm., 1997).

5.7 SYNOPSIS

In combination, Kluane, Wrangell-St. Elias, Glacier Bay, and Tatshenshini-Alsek Parks, Tetlin Refuge, and the Russell Fiord and Endicott River Wilderness Areas constitute the largest internationally protected area in the world and are second only to Greenland National Park as the world’s largest contiguous protected area. Superlatives abound to describe the region. It is among the most geologically diverse and active areas in the world and the location of some of North America's largest recorded earthquakes. It contains the highest coastal mountain range and the largest non-polar icefield in the world. It includes ten of North America's fifteen highest mountains as well as the continent's longest valley and piedmont glaciers. Coastal areas receive as much rainfall in one year as portions of the Amazon Rainforest and annual snow-fall in the Icefield Ranges exceeds that received anywhere else in North America. The region contains nearly one-third of the global population of Dall sheep and provides the only habitat in the world for the glacier bear. Several rare, threatened, and endangered species inhabit the region and populations of large mammals are among the largest in North America.

For the most part, the information, data, and maps presented as part of this synthesis represent the first time similar biophysical information from across the entire region has been combined. The results illustrate that the St. Elias Mountain Parks share several regional-scale ecosystem components with each other and with surrounding areas. Moreover, the synthesis illustrates that these shared components are influenced by common physical patterns and processes that occurring at both regional and sub-continental scales. Yet, the results of this synthesis also indicate that there are equally as many differences between the parks and their surrounding areas and that the biophysical character of each protected area is in many ways very different from the others. The following chapter analyzes these commonalities and differences with a view to assessing the relative degree to which the St. Elias Mountain parks and their surrounding areas function as a coherent ecological unit.

CHAPTER SIX

REGIONAL PROPERTIES AND ECOLOGICAL LINKAGES

6.1 INTRODUCTION

As illustrated by way of the synthesis presented in Chapter Five, several ecological features and processes are common to and shared across the St. Elias Mountain Parks. Despite its significant features and these regional ties, the extent to which the St. Elias region acts as a coherent ecological unit needs to be addressed prior to carrying out an assessment of the implications these have for regionally-oriented approaches to management and biodiversity conservation. This chapter addresses this by examining several of the regional ecological and geographical properties of the greater St. Elias ecosystem and assessing the relative degree to which the region is interconnected. Six specific ecological components are examined:

i. The physical foundation of the St. Elias and how it influences regional ecological patterns and processes;
ii. The influence of biogeographic centres of distribution on regional species distribution;
iii. The nature of transboundary wildlife movements;
iv. Landscape features which facilitate the movement of biodiversity throughout the region and those which serve as barriers to its movement;
v. The spatial distribution of large mammal populations and its influence on interpopulation dynamics (i.e metapopulation structure and dynamics); and,
vi. The distribution of viable protected and unprotected habitat throughout the region.

An assessment of the ecoregional and bioregional properties of the St. Elias region follows this regional ecological analysis and the chapter concludes with a summary of the most fundamental biophysical linkages between the region's parks and protected areas.

6.2 THE REGIONAL ECOSYSTEM

6.2.1 The Physical Foundation

Apart from its parks and protected areas, the physical landscape is the most apparent unifying characteristic of the St. Elias Region. Much of the region is dominated by high rugged mountains that share a common formative history by way of tectonic processes. These processes - as well as a multitude of geomorphological processes that shape the surface of the region - continue at all scales, maintaining one of the most active and dynamic physical environments on earth.

The entire ecology of the St. Elias region is, ultimately, an expression of its physical characteristics. Proximity to the Gulf of Alaska means that coastal areas experience a temperate climate with abundant precipitation and runoff. Air moving inland from the Gulf deposits much of its moisture in the form of snow on the coastal ranges of the St. Elias and Chugach Mountains. The result here is twofold: (i) the accumulation of snow in these ranges forming some of the largest glaciers in the world, and (ii) the creation of rainshadow conditions to the lee of these mountains.

While they are very different, these two zones are inextricably linked. Despite relatively little primary productivity, the icefields and glaciers are actually the lifeblood of the entire area lee of the coastal barrier mountains. By acting as the source of most of the region's watercourses they play a central role in the ecology of the greater St. Elias region. The most obvious role here is the conveyance of water to precipitation-poor areas and the species and even entire communities which are supported. Other, more subtle effects are also evident, such as the continual landscape and community change associated with braided stream courses and periodic events such as outburst flooding.

The variability in the physical environment, let alone the number of variables present, precludes even simple system modelling of regional ecology for analytical purposes here. Yet, the use of an indicator species can be instructive in illustrating the influence of the physical environment on the expression of biodiversity in the region, as well as the spatial influence it has at various levels of scale. Given the fact that it is the most habitat-specific of the six large mammals examined in the previous chapter, the mountain goat is used here for this purpose.

At the broadest scale, terrain and topography are the primary factors controlling the distribution of mountain goats in the St. Elias region. Quite simply, goats are absent from lowland areas because they require steep alpine habitat provided by mountain ranges. The distribution of goats within these mountain ranges represents the next spatial level of analysis and climate is the determining factor at this scale. While some populations exist in more northerly sections, mountain goat densities are highest and populations more continuous in more southerly areas experiencing direct influence of the coastal climatic regime. Steep terrain and cliffs are more lush in these areas, reducing intraspecific competition for resources which are already naturally limited by harsh environmental conditions. Determinants at a finer level of scale include edaphic and geological factors such as soil moisture and local geology, and microhabitat variables such as fine scale topography and microclimate. Variability in these conditions can render a mountain block virtually uninhabited by mountain goats despite appearing suitable from a regional perspective.

These are, of course, only the physical determinants for one species. Biological determinants such as interspecific competition and predation add an additional layer of complexity and are different for every species. Moreover, these variables must be considered in tandem for each species, or at the very least each guild, before even some assemblance of accurate system modelling can be obtained. However, the example does provide a relative measure of the importance of the physical environment in controlling the ecology of the St. Elias and how these variables interact across the entire region.

6.2.2 Centres of Biogeographic Influence

An examination of the species lists compiled for this project indicate that the St. Elias region is influenced by several major biogeographic regions and sub-regions. As illustrated in Figure 6.1, this includes species typical of Arctic, Boreal, Cordilleran, and Coastal ecosystems as well as species, subspecies and varieties theorized to have evolved in the Pleistocene Beringian refugium. In addition - although not specifically examined here - maritime components such as pelagic birds and aquatic mammals are also components of the region's fauna.

Not only does the intermixing of biogeographic zones account for the high level of species diversity for such a northern latitude but it also contributes to unusual species assemblages as well as the presence of entire vegetation communities typical of other

FIGURE 6.1: BIOGEOGRAPHIC ZONES INFLUENCING THE ST. ELIAS

(Located In Map Folio)

regions. Examples here include the intermixing of species typical of arctic areas with those typical of cordilleran areas in high alpine zones and the occurrence of grassland ecosystems in the Kluane Lake and Aishihik Lake areas (Sauchyn, 1982). Further, as shown in Table 6.1, it is because of this confluence of biogeographic zones that the extreme distributional limits of several species occur at or near the St. Elias region.

The discussions of population genetics in Chapter Five seem to support the model in Figure 6.1. As noted for the gray wolf and moose, the St. Elias region represents a region of subspecies overlap and is situated near the confluence of three of North America's four genetic clades of grizzly bear.

6.2.3 Transboundary Wildlife Populations

Wildlife has gained considerable attention in identifying linkages between parks and their surrounding areas in other regions and shared populations are often used a measure of connectivity between areas. Using this notion, Figure 6.2 conceptually illustrates the direct linkages between protected areas in the St. Elias region based on the large mammal ecologies and distribution mapping presented in Chapter Five. Evident from the figure is the notion that those protected areas separated by high rugged mountains and/or icefields have a reduced level of wildlife connectivity while those areas sharing more montane, subalpine and productive alpine habitat exhibit a higher level of connectivity. For example, Kluane National Park and the Kluane Wildlife Sanctuary have the strongest linkages amongst protected areas of the region because they share productive habitats where large mammals regularly move across park boundaries. Conversely, the link

Table 6.1: The St. Elias Region as a Biogeographic Tension Zone

Species listed here are at or near their extreme distributional limits in the St. Elias Region. Widely recognized subspecies are shown with scientific name. Nomenclature follows that of the checklists in Appendix E.

Distribution Type	Terrestrial Mammals(1)	Breeding Birds(2)
Northern Limit of Range (typically of Cordilleran origin)	Cougar, Mule deer, Mountain Goat, Alexander Archipelago Wolf *(Canis lupus ligoni)*	Blue Grouse, Rufous Hummingbird, Red-breasted Sapsucker, Western Flycatcher, Dusky Flycatcher, Stellar's Jay, Northwestern Crow, Chestnut-backed Chickadee, Mountain Bluebird, Townsend's Warbler, MacGillvary's Warbler, Western Tanager
Southern Limit of Range (typically of Arctic origin)	Tundra Vole, Singing Vole, Arctic Ground-squirrel, Collared Pika, Northern Red-backed Mouse, Brown Lemming, Collared Lemming (?)	Red-throated Loon, Red-necked Phalarope Oldsquaw, Least Sandpiper, Parasitic Jaeger, Gyrfalcon, Northern Shrike, Common Redpoll
Southeastern Limit of Range (typically of Beringian origin)	Dall Sheep *(Ovis dalli dalli)*, Alaskan Moose *(Alces alces gigas)*, Alaskan Marmot, Barren-ground Caribou *(Rangifer tarandus granti)*	Surfbird, Aleutian Tern, Arctic Warbler
Western Limit of Range (typically of Boreal origin)	Boreal Gray Wolf (*Canis lupus occidentalis*), Woodland Caribou *(Rangifer tarandus caribou)*, Heather Vole	Greater Yellowlegs, Yellow-bellied Sapsucker, Red-breasted nuthatch, Tennessee Warbler, Purple Finch
Northwestern Limit of Range (typically central Continental origin)	Woodchuck, Long-tailed Weasel, Wood Bison*, American Water Shrew, Least Chipmunk, Bushy-tailed Wood Rat	Gadwall, Hooded Merganser, Sora, Killdeer, Great-blue Heron, Red-tailed Hawk, Common Nighthawk, Barn Swallow, Brown Creeper, Golden-crowned Kinglet, Common Yellowthroat, American Redstart, Song Sparrow, Chipping Sparrow, Red-winged Blackbird
Disjunct, Regional, or Isolated Populations	None identified.	Redhead, Ring-necked Duck, Snow Bunting, Smith's Longspur, Lapland Longspur, Brewer's Sparrow

(1) Based on range maps in Chapman and Feldhamer (1982) and Hall (1981).
(2) Based on range maps in Scott (1987)
(*) Introduced populations. See Wright (1982) for a discussion as to whether or not it has been introduced or re-introduced.
(?) Questionable record

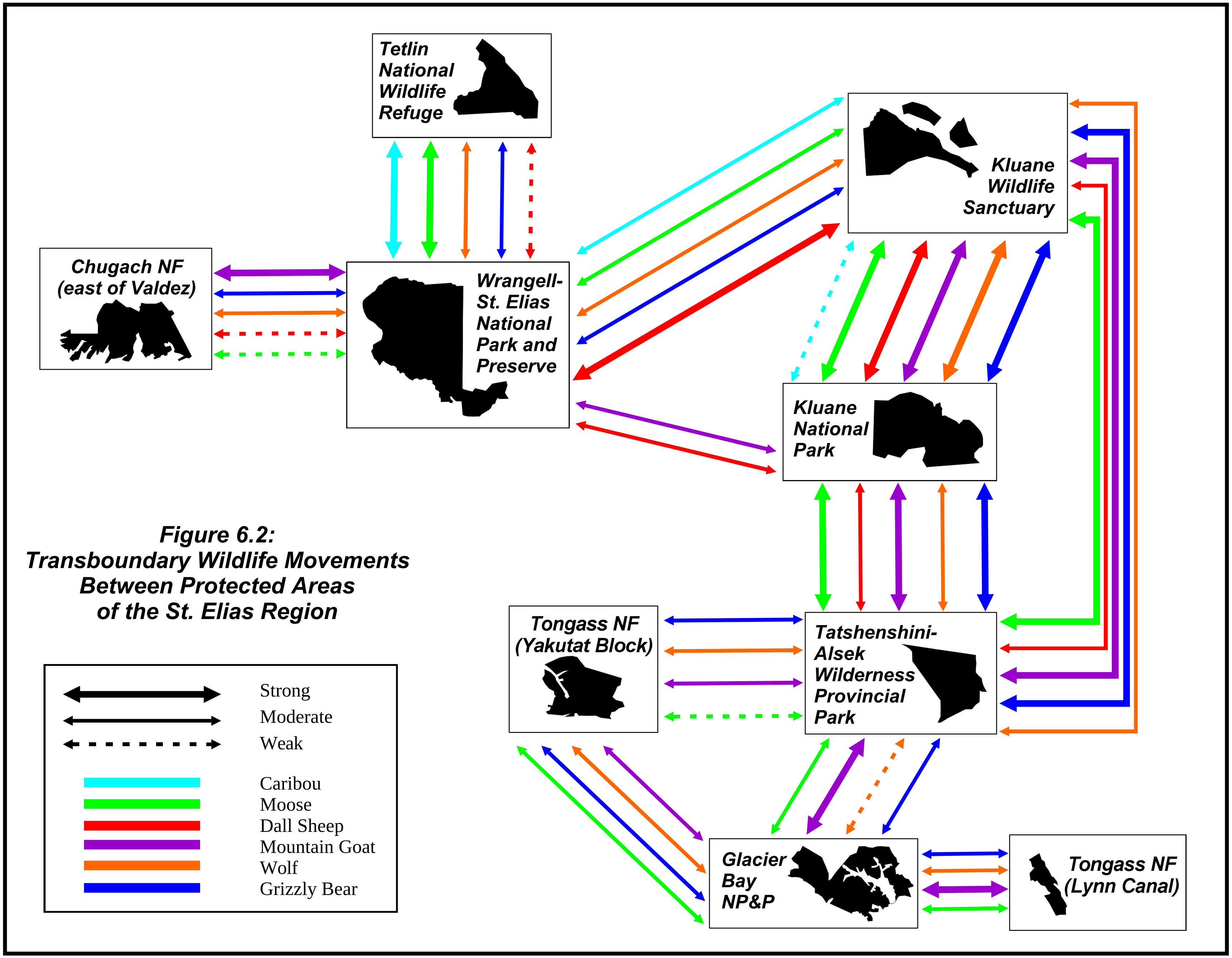


Figure 6.2: Transboundary Wildlife Movements Between Protected Areas of the St. Elias Region

between Kluane National Park and Wrangell-St. Elias National Park and Preserve is the weakest due to the barrier presented by the icefields and Icefield Ranges.

In addition to the linkages illustrated in Figure 6.2 are aquatic linkages between the parks and protected areas as well as transboundary populations of birds and other mammals. Willson and Halupka (1995) describe the nature of salmon as a keystone species in Pacific Northwest ecosystems. Using this concept, shared salmon runs can be used as indicators of ecosystem linkages between protected areas of the St. Elias region. Figure 5.7 illustrated regional drainage patterns in the St. Elias region and can be used as a relative indicator of linkages here, although examination of specific salmon runs is required to develop a model like that in Figure 6.2.

The nature of transboundary populations amongst birds and other mammals can only be hypothesized here because of the limited data on these species (apart from presence/absence statistics) which was examined as part of this study. However, it is not unreasonable to suggest that transboundary movements would be more prevalent where two areas share habitat and/or migration corridors for a given species rather than simply where they bordered with each other. This is examined in the following two subsections.

6.2.4 Barriers and Facilitators to Biodiversity Movement

In conjunction with previously published material, an overlay of various wildlife and physiographic map layers created in the GIS was used to identify areas that act as a hindrance to the movement of biodiversity and areas that appear to facilitate the movement of biodiversity. As illustrated in Figure 6.3, the icefields of the Icefield Ranges,

FIGURE 6.3: BARRIERS & FACILITATORS OF BIODIVERSITY MOVEMENT

(Located In Map Folio)

Wrangell Mountains, Fairweather Range, and Coast Mountains were identified as major impediments to the movement of biodiversity. Not only do these areas present a formidable physical barrier to movement, but conditions are so harsh in these areas that attempts by wildlife at traversing them are commonly met with failure (Krajick, 1998).

Conversely, several areas facilitate the movement of biodiversity, most notably the low elevation valleys of the Alsek, Tatshenshini, Endicott, Copper, and Chitina Rivers. As noted previously, these areas have acted as corridors in the range expansion of several species and act as connective corridors for the movement of individuals between populations. However, it is likely that the relative importance of the Copper River as a movement corridor decreases for terrestrial vertebrates south of the confluence with the Chitina where Woods and Baird Canyons may act as a barrier to these species. This is illustrated by the fact that moose did not naturally emigrate to the Copper River delta, but have thrived there since their introduction by humans.

In addition to these river valleys, the Gulf of Alaska Coast and the Shakwak Trench also act as lineaments for biodiversity movement. Each of these areas are known as migratory bird flyways (Wattereus *et al.*, 1989) and have acted as corridors in the dispersal of wolves and moose.

Figure 6.3 was not generated entirely by way of a systematic, quantitative spatial analysis. Instead, the process was rather qualitative in nature, and the relative importance of some of the minor corridors can only be assumed. Yet, such a spatial model has not been previously developed and obviously provides a framework upon which more detailed spatial modelling and empirical investigations can be built.

6.2.5 Wildlife Metapopulations

In its most basic form, a metapopulation is defined as a “population of populations” loosely connected through the movement of individuals (Hanski, 1991). The “classic” metapopulation model characterizes a metapopulation as a collection of individual populations occupying habitat patches of similar size and quality but separated from each other by unsuitable habitat. Populations in patches of suitable habitat are subject to extinction processes while unoccupied suitable habitat patches are subject to colonization events by individuals (Hanski and Gilpin, 1991). The long term persistence of a metapopulation is therefore dependent on a balance between extinctions and colonizations, or a surplus of colonizations. (Hanski, 1991).

The second metapopulation structure often described is the mainland-island model formalized by Boorman and Levitt (1973) where one population existing in a single high quality habitat patch is so large that it is resistant to extinction pressures. Extinction and colonization occur among smaller satellite populations, but are nearly irrelevant to the persistence of the metapopulation, since this is assured by the mainland (Hanski and Thomas, 1994; Harrison, 1994).

While these two models continue to be utilized, it is now generally recognized that metapopulations can occur in a wide variety of spatial patterns (Harrison and Taylor, 1997). A useful perspective is to consider the two dominant models as “two extremes of a continuum” (Hanski and Gyllenberg, 1993), defined by an increasing variation in the size of habitat patches and/or individual populations. This notion of a continuum in the spatial structure of metapopulations has lead to a broader conceptualization of metapopulations as "spatially distributed populations among which dispersal and turnover are possible but do not necessarily occur" (Harrison, 1994).

The spatial distribution of each of the six large mammal species detailed in Chapter Five is analyzed below to assess the degree to which individual populations are linked in the St. Elias region and, in turn, assess the relative degree to which seemingly separate populations are dependent on each other.

Dall Sheep

Bailey (1992) defined a metapopulation of wild sheep as “local populations (herds) interconnected by movements of animals across inter-herd corridors” (pg. 49). He proposed three types of metapopulations and various intergrades for bighorn sheep *(Ovis canadensis)* that are equally applicable to thinhorn sheep. Of these three types, the *megapopulation* appears most similar to the spatial population structure expressed in the St. Elias region. Bailey defines a megapopulation as a group of sheep containing over 1000 animals which is distributed rather continuously over a large area but is organized into herds that use different seasonal ranges. Barriers between these herds are rather insignificant and movement of individual sheep between herds occurs annually. Thus, the core of distribution in the St. Elias region - the Wrangell Mountains, the northern sections of the Kluane Wildlife Sanctuary, and the greenbelt of Kluane National Park - could be considered a megapopulation. Bailey also notes that megapopulations may include satellite populations which are comprised of several small peripheral herds occupying secondary habitat patches. This spatial structure is evident in the sheep population of

Tatshenshini-Alsek Wilderness Provincial Park, and the transboundary population between Wrangell-St. Elias and Kluane National Parks.

Whether or not the individual herds of the core megapopulation should be considered demes within a population or populations within a metapopulation is a point of debate. However, given the large area involved, the large herd sizes expressed in this area, and the distinct habitat patches illustrated in Figure 5.14 combined with the habitat specificity of the species, a metapopulation is presumed likely.

Caribou

Like Dall sheep, the spatial distribution of caribou into discrete herds initially suggests a metapopulation structure. Then, with the benefit of historical evidence, population statistics, and the results of capture-relocation studies, it becomes readily apparent that caribou also express population dynamics indicative of a metapopulation structure. This is a notion formally proposed by Theberge (1998) but yet to be examined in any detail.

The herd is the most fundamental population unit of caribou and each herd can be considered a distinct population. As described in Chapter Five, caribou have a high range fidelity and utilize traditional seasonal ranges annually. However, several factors point toward the existence of classic metapopulation dynamics in caribou of the greater St. Elias region and, indeed, well beyond. Most apparent here is periodic exchange of individuals amongst herds and - over the long term - the emergence of new herds and extinction of others. Indeed, when considered over the long term, it becomes readily apparent that caribou populations are quite dynamic - both spatially and numerically, the two of which are likely not unrelated.

The case of the Nelchina and Mentasta herds is instructive here. Given the significant winter range overlap exhibited amongst these herds, Lieb *et al.* (1994) set out to quantify, among other things, ingress-egress between the herds. Based on capture-relocation monitoring of 175 cows, they characterize the interchange of individuals between the Nelchina and Mentasta herds as rare, but note that interchange of young females may be higher as they have yet to formulate fidelity to calving areas. What they fail to note however, is that the exchange of bulls may be higher still because they need not remain faithful to calving areas. Moreover, it is likely that some Nelchina bulls breed with Mentasta cows (and vice versa) during the rut, facilitating exchange of genes rather than individuals (Mitchell and Barten, pers. comm., 1997). Regardless of the extent of interchange, it is clearly evident that while herd structure is maintained, exchange of individuals and/or genes does occur. This is particularly noteworthy given the current classification of Mentasta caribou as a woodland herd and Nelchina caribou as a barren-ground herd.

Also instructive in demonstrating the nature of population dynamics amongst caribou herds is the case of the several small woodland herds inhabiting the southern Yukon. Haber (cited in Gauthier and Theberge, 1985) suggested that some of these herds, including the Burwash/Kluane and Aishihik, originated as fragments from the Fortymile herd. It would not be unreasonable to hypothesize that the Mentasta, Macomb, and/or Chisana herds originated in the same fashion from the Nelchina herd. This scenario clearly resembles the spatial structure of the mainland-island metapopulation model, in which case the population fluctuations presented in Chapter Five for the four woodland herds would be expected.

Gray Wolf and Grizzly Bear

The extent of ingress-egress amongst wolf packs in the greater St. Elias region suggests that packs are more synonymous with demes than individual populations. Furthermore, the nature of long-distance dispersal exhibited by wolves combined with the results of recent genetic analyses suggests that wolves in North America are more interconnected than previously imagined (Wayne *et al.*, 1992). As such, it appears as though wolves are divided into two distinct populations in the greater St. Elias region: an interior population and a coastal population. The extent of the linkage between the two populations can only be hypothesized, but given the potential subspecific designation of the southeast Alaskan wolf *(C.l. ligoni)* and the previously noted regional-scale barriers and facilitators of wildlife movement, this is not an unreasonable supposition. The interior population could itself be divided into two subpopulations; a Yukon-British Columbia population and an Alaskan population. However, the division between the two is not distinct in the zone of overlap at the junction of the Kluane Wildlife Sanctuary, Wrangell-St. Elias, and Tetlin NWR.

For similar reasons, a division between coastal and interior grizzlies into two separate populations also appears logical. Interior grizzlies should certainly be considered a distinct population. Although the extent of interchange between interior Alaska bears and Yukon bears may be reduced due to the Icefield Ranges, their large home ranges, low densities (in comparison with ungulates) and continuous distribution seem to support this hypothesis. Yet, despite their capability of long-distance dispersal, the movement barrier imposed by the Icefield, Fairweather, and Boundary Ranges is formidable, leaving only a few corridors for exchange between the coast and interior. While the extent of exchange between the two zones has not been quantified, it is almost certainly much less than that which occurs within each zone.

Mountain Goat

In discussing the relation between metapopulation structure and distributional limits of a particular species, Brown and Lomolino (1998) state that "they (metapopulations) are especially likely to occur on the periphery of species ranges and to contribute to dynamic shifts in range boundaries". This appears to be the case with mountain goats in the St. Elias region. While their range extends west to the Kenai Peninsula along the south coast of Alaska, the St. Elias region actually marks the northernmost point of distribution for the mountain goat (Chadwick, 1983). Given this distribution, the St. Elias populations could be considered "range-edge" in nature.

In combination, the distributional pattern and densities of mountain goat in the St. Elias Region presented in Figure 5.15 are suggestive of the core-satellite (mainland-island) metapopulation model. Populations located further south exist in much higher densities than those to the north because of the more favourable environmental conditions described previously. These more southerly populations could act as sources of individuals populating peripheral areas of marginal habitat incapable of supporting the denser populations characteristic further south. Because of their smaller size these peripheral populations are more susceptible to stochastic extinction events and are, therefore, more volatile in nature while the larger populations further south are more stable.

While the above model at first appears logical, empirical evidence in the form of data from collared individuals is sparse. Moreover, given Klein's (1965) hypothesis that mountain goats colonized Yukon and Alaska by way of two separate routes (an interior route and a coastal route) - combined with more limited movement corridors between high density (i.e. coastal) and low density (i.e. interior) populations - it is apparent that spatial structure of mountain goat populations is significantly more complex than the model outlined above. Yet, what remains apparent is that peripheral populations located in the Kluane Ranges as well as the isolated population located in the heart of the Wrangell Mountains occur at significantly lower densities than those in Glacier Bay National Park and Tongass National Forest, are substantially more susceptible to a multitude of extinction pressures and are likely reliant on the persistence of these other high density populations as "sources" of immigrating individuals.

Moose

Outside of the icefield areas, moose are distributed throughout the St. Elias region. Yet, apart from areas of outstanding habitat - notably the Copper River Lowlands and Copper River Delta - moose densities are quite low in comparison to populations elsewhere in North America. Given these low densities and known behaviour of the species, it is quite reasonable to suggest that animals concentrating in fall or late winter habitat be considered members of the same deme. Yet, the fact that moose do not form a herd structure and remain rather solitary for the remainder of the year prevents delineation of the regional population into distinct populations without sufficient monitoring data. Nevertheless, historical data regarding the recent establishment of moose in southeast Alaska does support a stronger division between coastal and interior demes into separate populations.

Breeding Birds

In addition to the large mammal metapopulation structures described above, the St. Elias region also harbours breeding populations of six species of birds which are isolated or disjunct from the core of their continental range. These include two ducks: ring-necked duck (*Aythya collaris*) and redhead (*Aythya americana*), and four passerines: snow bunting (*Plectrophenax nivalis*), Lapland longspur (*Calcarius lapponicus*), Smith's longspur (*Calcarius pictus*), and Brewer's sparrow (*Spizella brewerii*). The two species of ducks are typically continental breeders and utilize the Tetlin flats and other large interior wetlands for nesting. The first three passerines are arctic nesters and the populations found in the St. Elias region utilize the high alpine habitats of the St. Elias and Wrangell Mountains. The core continental breeding range of the Brewer's sparrow is located much farther south in the US Rockies. Recent investigations by Doyle (1997) on the St. Elias population suggests that it may warrant supspecific designation.

When examined at a very broad scale in the context of their entire continental range, these species resemble the island populations in the mainland-island metapopulation structure (see Harrison *et al.*, 1988). That is to say, the survival of these populations is likely insignificant in ensuring the survival of the species as a whole. Yet, as illustrated in the case of the Brewer's sparrow, allopatric speciation may occur in these populations and result in the creation of a new variety, subspecies, or - given enough time - even species.

6.2.6 Regional Habitat Distribution

Despite the immense size of the transborder protected area of the St. Elias region, a large percentage of its total area is actually inhospitable to a broad range of species. Figure 6.4 illustrates this notion by defining areas of "viable" habitat which are protected in the Greater St. Elias region. Viable habitat is defined here as those areas of sufficient size and productivity to contain a set of species and communities considered representative of the ecoregion as a whole. As shown in the Figure, roughly half of the entire transboundary protected area is considered inhospitable - composed mainly of permanent ice and bare rock at high elevations. Although recent research has shed light on the biological diversity contained on icefield nunataks in the St. Elias region (Hik, pers. comm., 1998), these areas do not support the diversity contained in areas outside the major icefields and do not fit the definition of viable utilized for this regional perspective.

Based on figures estimated by way of the regional GIS, no more than 60 percent of the total area in any of the four national parks and equivalent reserves is viable habitat. In fact, less than 40 percent of Kluane National Park and Reserve can be considered viable enough to contain a representative set of species and communities. At 60 percent, Wrangell-St. Elias National Park and Preserve boasts the highest level. The trend with respect to viable habitat is actually counterintuitive; the protected areas which

FIGURE 6.4: HABITAT VIABILITY AND ITS PROTECTION

(Located In Map Folio)

provide the least amount of protection actually contain the highest percentages of viable habitat. Those areas providing the strongest protection contain the least.

The spatial distribution of viable habitat is equally relevant here. Much of the inhospitable terrain of each park is located in the Icefield and Fairweather ranges which form the backbone of the transborder protected area. As a result, only a small percentage of viable habitat is shared amongst the protected areas. Instead, the individual protected areas share most of their viable habitat with adjacent, unprotected areas.

6.3 ECOREGIONAL AND BIOREGIONAL PROPERTIES

Wiken (1986) defines an ecoregion as an ecologically distinct area resulting from “the mesh and interplay of the geologic, landform, soil, vegetative, climatic, wildlife, water, and human factors which may be present”. As illustrated in Figure 6.5, the St. Elias region is composed of several different ecoregions of intermediate scale (Bailey’s (1995) “ecoprovinces”), each characterized by its own set of species interactions, communities, and landscape types. At a broader scale, the St. Elias spans portions of two ecological zones or “domains”: a coastal belt that includes all of southeast Alaska, the southern portions of the Haines Triangle, the southwest corner of Kluane National Park and the Chugach Mountains, and an interior area that incorporates the rest of the region and extends well beyond to the north and east. It is important to note here that all ecoregional classifications of northwestern North America reviewed here (e.g. Gallant *et al.*, 1996; Wiken, 1986; Bailey, 1995) make this distinction between coastal and interior areas, not just that shown in Figure 6.5.

FIGURE 6.5: ECOREGIONS OF NORTHWESTERN NORTH AMERICA

(Located In Map Folio)

The biophysical synthesis presented in Chapter Five supports the division of the St. Elias region into two broad ecological zones corresponding to coastal influences. Climate, and its influence on hydrology, is the fundamental cause here as the temperature and moisture conditions are significantly different where a direct coastal influence is felt. Vegetation is the moist evident biological manifestation of these climatic differences. Coastal areas support lush vegetation communities typical of the temperate rainforest biome while interior areas are much drier and support ecosystems typical of the boreal forest biome. Also of note with respect to biodiversity is the manner in which all of these factors have contributed in influencing wildlife ecology. The region's two large carnivores provide ample evidence of the differences here. Chapter Five demonstrated the significant differences between grizzly bears and wolves inhabiting coastal areas and those occupying interior areas. Differences in prey species and availability contribute significantly to the behaviour, density, and even morphology within these species.

While the parks and protected areas of the St. Elias region may not be characterized by a single ecological hierarchy or classification, it could be argued that they are part of the same bioregion. Several definitions have been used to describe the concept of a bioregion (e.g. Berg and Dasmann, 1977; Parsons, 1984). A representative definition is offered by Miller (1996) who describes a bioregion as "a geographic space... characterized by its landforms, vegetative cover, human culture, and history."
Given this definition, consideration of the human environment is equally important as the biophysical environment in assessing the bioregional character of the St. Elias region. Institutionally, the most apparent characteristic of the region is the dominance of parks

and protected areas. This, in turn, spawns numerous connections and linkages throughout the region, from land use to the very nature of the landscape. Furthermore, while land use beyond these areas varies at a local level, it is of the same fundamental nature throughout the region. Population patterns are also similar throughout the region, with small settlements and widely spread homesteads being dominant. As with the biophysical environment however, differences exist between the coast and interior areas, related mostly to primary industries such as forestry, fishing, and mining.

Native American cultural groupings are often used as a guidance in bioregional boundary delineation (Aberley, 1993; Parsons, 1985). As illustrated in Figure 6.6, the St. Elias region is home to several different North American aboriginal cultural and language groups. Yet, none of these groups has traditional homelands contained completely within the St. Elias region. Like the tectonic terranes that form the physical foundation of the region, the biogeographic realms which control the expression of biodiversity, and the parks and protected areas which have influenced the contemporary human environment of the St. Elias region, the traditional cultural environment of the greater St. Elias is an area of convergence. Ultimately, if one is to consider the greater St. Elias region as a bioregion, this is its basic unifying characteristic.

6.4 SUMMARY AND DISCUSSION

The broad ecological connections between Kluane National Park, Tatshenshini-Alsek Wilderness Provincial Park, and Glacier Bay and Wrangell-St. Elias National Parks and Preserves are clearly evident from the synthesis presented in Chapter Five and the regional

FIGURE 6.6: NATIVE LANGUAGE GROUPS OF THE GREATER ST. ELIAS

(Located In Map Folio)

analysis presented above. Their physiography and weather are each regulated by the same broad-scale processes, resulting in similar patterns of topography and hydrology. To greater or lesser extents, the set of species harboured in each protected area is influenced by the fact that several biogeographic provinces converge on the region. Relatively independent wildlife populations shared by one or two protected areas are linked to other populations by way of immigration/emigration and dispersal, creating dynamic metapopulations where the existence of one population is tied to the continued existence of the others.

Despite these connections, it is also obvious that these four areas have ecological linkages with adjacent less protected and unprotected areas that are equally as strong, and in many cases stronger, than they are among themselves. For example, Kluane National Park and Wrangell-St. Elias National Park and Preserve share a 274 km boundary. Yet the physical barrier created by the Icefield Ranges has meant that biological linkages between these two largest protected areas are relatively small in comparison to their linkages with other areas. Further, coastal areas experience dramatically different climatic conditions than interior areas, resulting in the expression of a completely different suite of ecosystems.

The following chapter analyzes the implications of these regional patterns and processes for ecosystem-based management of the St. Elias Mountain Parks and adjacent areas and provides both general and specific recommendations for their management as well as the conservation of biodiversity throughout the region.

CHAPTER SEVEN
IMPLICATIONS FOR REGIONAL MANAGEMENT

7.1 INTRODUCTION

The St. Elias Mountain Parks are clearly part of a complex set of interconnected ecosystems. This is particularly evident in light of the fact that the St. Elias region appears to lie at the confluence of a number of regional ecosystems (i.e. ecoregions). Ultimately then, it is difficult to define a single and distinct ecologically-based boundary for integrated management that includes each of the region's parks and protected areas. Instead the greater ecosystem of each protected area is different from that of the others; even though it may contain a portion of - or all of - another protected area. Rather than a regional boundary, the regional ecology of the St. Elias Mountain Parks seems to advocate a more process-oriented approach to management wherein the exact boundaries of management are of secondary importance to the development of a coordinated set of principles, goals, and objectives to guide planning and management.

This chapter analyzes the implications that the previously described regional ecological features, patterns, and processes have for ecosystem-based management of the St. Elias Mountain Parks and adjacent areas within the context of this reality. It first focuses on broader, more conceptual management implications for the region as a whole. It then focuses on the parks and protected areas of the region and presents several recommendations for their planning and management - specifically related to integrating management with surrounding unprotected areas and coordinating management cooperation. Finally, it recognizes the need for integrated management and cooperation in the region to extend beyond government agencies and include all relevant stakeholders.

7.2 GENERAL IMPLICATIONS FOR ECOSYSTEM MANAGEMENT

As discussed in the second chapter, two of the primary goals in ecosystem management are to maintain ecological integrity and sustain biodiversity and ecosystem processes at a regional scale (Keystone Center, 1996). Grumbine (1994) identified five general objectives often identified to attain these goals. The fourth objective has been adjusted slightly here, based on the review of the literature in Chapter Two to include a spatial scale component as well as the temporal component identified by Grumbine:

i. Maintain viable populations of all native species in situ;
ii. Represent, within protected areas, all native ecosystem types across their natural range of variation;
iii. Maintain evolutionary and ecological processes;
iv. Manage over periods of time long enough, and across spatial scales large enough, to maintain the evolutionary potential of species and ecosystems;
v. Accommodate human use and occupancy within these constraints.

Agee (1996) evaluated these broad objectives and found them to be appropriate for parks and protected areas. They are discussed individually below within the context of the regional biophysical synthesis and regional analysis presented in Chapters Five and Six with a view to assessing implications for management of the St. Elias Mountain Parks and surrounding areas.

7.2.1 Maintaining Viable Wildlife Populations

A population is considered viable when it "maintains its vigour and its potential for evolutionary adaptation" (Soule, 1987, pg. 1). Regardless of the specific factors contributing to the decline of a species or population, the overriding general rule in assessing population viability is that smaller populations are more vulnerable to extinction (Pulliam and Dunning, 1997). Viable populations are large enough and diverse enough to withstand intrinsic population variables such as demographic stochasticity and genetic deterioration (Soule and Simberloff, 1986). With very few exceptions, viable populations are generally in the order of thousands of individuals (Thomas, 1990).

At its most basic level, ensuring a viable population translates into the management objective of ensuring the existence of a large population. The most apparent implication for the St. Elias region in this instance is the need to ensure that human activities do not cause or exacerbate the decline of the regional population to the point where it becomes vulnerable to extinction. Specifically, this necessitates a management focus on those species most at risk in the region (Noss, 1992). As discussed by Primack (1993), Theberge (1993) and Woodruff (1989), this includes species with large home ranges (e.g. large carnivores such as grizzly bear), species associated with specialized habitats (e.g. alpine obligates such as collared pika), species sensitive to human disturbance (e.g. secretive species such as wolverine), migratory species (e.g. caribou), species occurring in low numbers and/or at low densities (e.g. rare, threatened or endangered species such as peregrine falcon), and species with isolated, fragmented or sporadic patterns of distribution (e.g. the population of *Cryptantha shackletteana* in Wrangell-St. Elias)

Given the fact that the four core protected areas of the St. Elias contain significantly less viable habitat than their total areas might suggest, it is doubtful that they contain a viable population of any wide-ranging carnivore (i.e. grizzly bear, gray wolf, black bear, wolverine) on their own. In combination they may sustain what would numerically be considered a viable population but, as was illustrated in Figure 6.2, exchange of individuals is not equally or evenly distributed among these areas. Furthermore, given their seasonal movement patterns, the protected areas cannot maintain a viable caribou population on their own and it is questionable whether they can maintain a viable moose population. It is apparent then that the maintenance of viable populations of at least the aforementioned six mammals is dependent on the persistence of populations of these species in adjacent unprotected areas. Yet, it is in these areas that human activities have the greatest potential for negative impacts on these species. Furthermore, anthropogenic pressures on "protected" populations are not entirely absent either given the fact that sport and/or subsistence hunting and trapping is permitted throughout much of the region. The implication here is that the protected areas cannot be relied upon alone to ensure the maintenance of viable populations and that a coordinated intergovernmental approach to managing wildlife populations is necessary.

7.2.2 Representing Native Ecosystem Types

As described in section 5.4, the nature of existing ecosystem classification in the greater St. Elias region precluded a quantitative examination of ecosystem representation within its protected areas. However, the results of the broad scale analysis undertaken in section

5.4 as well as 6.2.6 do have significant implications with respect to representing all native ecosystem types across their natural range of variation within protected areas.

Noss (1992) describes how the establishment of large protected areas serves as one method of attaining a high level of biodiversity representativeness. Yet, despite their total combined area, less than 55 percent (54,500 km^2) of the four core protected areas of the St. Elias is considered “viable”. This compares with 78 percent (28,212 km^2) of the surrounding national forests and wildlife sanctuaries and 93 percent (94,567 km^2) of the surrounding unprotected areas mapped at 1:250,000. Further, using the basic land cover analysis results presented in Chapter Five, roughly one half of the viable habitat contained within the four protected core areas is above the tree line, while much of the surrounding less protected and unprotected areas are below treeline. The result here is that the four national parks and equivalent reserves are actually less representative of their regional surroundings than they are of each other. This indicates that forested ecosystems - despite their prevalence in surrounding areas - are under represented in the four core areas.

The management implications here are significant in that they confirm the need for conservation-based forest management in the areas outside of the four protected cores. Apart from a Yukon territorial park centred on the Klutlan Glacier, it is unlikely that any other protected areas will be established in the St. Elias Region. Thus, the integrity of forest ecosystems - whether they be montane, boreal, or coastal - in the greater St. Elias Region is almost entirely dependent on sustainable management of the unprotected matrix.

7.2.3 Maintaining Ecological Processes

During this century, ecology has undergone a shift from emphasizing the "balance of nature" to the "flux of nature" (Pickett and Ostfeld, 1995). Traditionally, ecology placed emphasis on a stable point equilibrium of ecological systems, suggesting that such systems were structurally and functionally complete and, therefore, closed and self regulating. The focus of such study was "the end points of ecological processes and interactions" (Pickett *et al.*, 1992). In contrast to this, the new ecological paradigm, referred to here as the *nonequilibrium paradigm*, emphasizes process rather than end point and stresses ecological systems as open and dynamic (Fielder *et al.*, 1997).

The most significant influence of nonequilibrium thinking on protected areas management - indeed environmental planning and management as a whole - has been the development of an emerging management goal: preserving ecological processes as opposed to specific features and allowing such processes to occur in a fashion unhindered by human interference to the maximum possible extent (Western, 1989; Walker, 1989; Pickett *et al.*, 1992; Meffe and Carroll, 1997). In the words of McNaughton (1989), "conservation should be based on a policy of maintaining ecosystem processes, so management should be as noninterventionist as is feasible but as interventionist as is necessary to achieve that objective" (pg. 120).

Ecosystem processes occur at all scales. Landscape-scale and regional-scale natural disturbances such as forest fires and spruce beetle infestations, glacially-dammed lakes and outburst floods, and meta-scale wildlife migration (e.g. caribou) and dispersal (e.g. wolves) still occur throughout the entire St. Elias Region. Except in special management circumstances, these and other broad-scale processes proceed unhindered by human intervention in the region's four core protected areas. Beyond the four core areas the continuance of these broad-scale processes is mostly tied to the fact that the region remains in a largely wilderness state.

Applied studies of ecosystems across North America have demonstrated that maintaining wilderness character is critical to maintaining regional-scale processes and ecological integrity. Yet the continuance of many of these regional-scale processes in the St. Elias region is as dependent on the unprotected matrix as it is on the region's protected areas. Given this relationship, it is imperative that broad-scale ecosystem processes are considered in the management and land-use planning of unprotected lands and that these efforts strive to maintain them in perpetuity.

The goal of maintaining evolutionary processes yields a broad management implication that is the same as that outlined in section 7.2.1. If we are to strive to maintain evolutionary processes, it is imperative that viable populations are maintained. Just as important is the need to maintain the maximum level of genetic diversity possible and not to hinder the spread of this diversity between populations. Particularly relevant here is the concept of metapopulations in facilitating this genetic diffusion and, therefore, the need to maintain the habitat corridors and dispersal paths and processes that link populations.

7.2.4 Enlarging Management Scales

The notion of carrying out management at appropriate time frames and at appropriate spatial scales is central to ecosystem management (Franklin, 1997). Determining the appropriate scale is the first logical step in working towards this goal. This thesis has clearly argued for the need to enlarge the spatial scale of management in the St. Elias region by considering the linkages between protected areas as well as the regional ecological features and processes that act to bind ecosystems and/or their components. Given the reduced emphasis placed on environmental change the need for an enlarged temporal management scale is less evident. Yet the dynamic nature of the region and the potential for increased human-induced change certainly warrant such consideration. Furthermore, given the spatial-temporal links evident in ecological processes such as natural disturbances, an expanded temporal scale is the natural extension of an enlarged spatial scale.

Unfortunately, the task of expanding temporal scale is likely to be even more difficult than enlarging the spatial scale of management. Establishing an historical range of ecological variability through research and monitoring is seen as a fundamental component in helping to overcome these difficulties in the St. Elias region. If change is recognized as a natural component of ecological systems, then the nature of such change must be characterized. Such research and monitoring includes studies of both natural and human induced environmental change to identify the time frames at which various ecological processes occur and how human activity affects such change.

Adaptive management appears to be well suited as a method of incorporating temporal considerations - particularly the notion of natural variability - into regional ecosystem-based planning and management. In the words of Grumbine (1994), adaptive management "assumes that scientific knowledge is provisional and focuses on management as a learning process or continuous experiment where incorporating the results of previous actions allows managers to remain flexible and adapt to uncertainty" (pg. 31). Franklin (1997) notes that adaptive management approaches can be either formal or informal but that in any case "a scheme that provides for the systematic collection of information and its feedback into the decision-making process is required" (pg. 30). Figure 7.1 conceptually illustrates these feedback paths within the context of the adaptive management process.

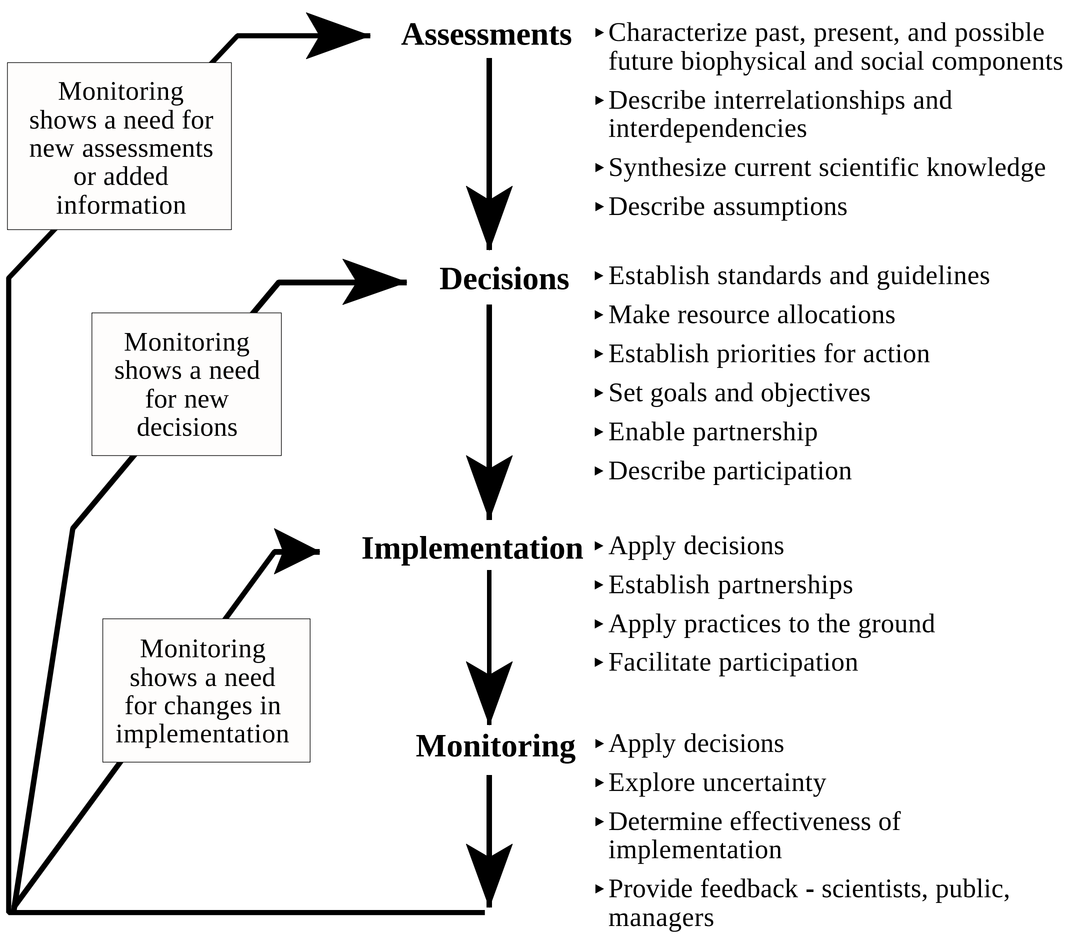


Figure 7.1: The Process of Adaptive Management
(redrawn from Agee, 1996)

Two notions are fundamental to adaptive management: (i) that scientific knowledge is incomplete, and that decision making must therefore proceed based on the best available information, and (ii) that both ecosystems (i.e. the system being managed) and society (the conditions under which the system is managed) are constantly changing and that management must account for, and adapt to, these changes. It is this recognition of uncertainty and the potential for change that suggests adaptive management as a useful framework for incorporating temporal considerations into management of the St. Elias region.

7.2.5 Accommodating Human Use

Accommodating human use within the constraints described above is the most challenging of the five broad objectives for regional ecosystem management. Given its broad-scale, the results of this study can not be used to evaluate the suitability of resource use and development in the St. Elias region on a site specific basis. However, a number of generalizations can be made with respect to the direction that regional land-use and development should take.

Despite recent criticism of the idea of wilderness (e.g. Callicott, 1994/95) and a longstanding conflict over the practice of preserving it, there is clearly a link between wilderness and ecological integrity in the St. Elias region. Quite simply, it is because of its predominantly wilderness character that the St. Elias has a high degree of ecological integrity. If this integrity is to be maintained, then wilderness preservation must remain as one of the fundamental objectives in managing the region. In light of this, it is imperative that both the degree of wilderness preservation afforded by the region's parks and protected areas, as well as the amount of wilderness protected by these areas, is not reduced.

The fact that wilderness preservation must remain a high priority in regional management should not be interpreted to suggest that all future development in the less protected and unprotected areas of the St. Elias region should be prevented, or that all existing activities be stopped. However, it should be interpreted to mean that these activities must occur within the context of preserving the overall wilderness character or quality of the region, must be carried out with minimal impact on the ecological integrity of protected wilderness and, therefore, must proceed with caution.

One specific tool that can be used to ensure that human use and occupancy of the St. Elias region occurs within these broad objectives is cumulative effects assessment (CEA). Hegmann (1996) reviewed multiple definitions of CEA and defined it as an assessment of environmental impacts that includes "consideration of the contribution of effects from other existing projects and possible future projects" (pg. 26). It incorporates "an estimate of the incremental impact of a proposed project and an estimate of the total impact after addition of the increment" as well as "an assessment of the eventual additive or synergistic result of many incremental impacts" (pg. 26).

Given the limitations imposed on land use within the protected core of the St. Elias region, impacts associated with large resource development activities will not arise from within the four national parks and equivalent reserves. Instead, most internal impacts to the protected areas will arise from smaller undertakings - for example, trail building and recreational facility development - which, when examined independently, may not appear to have any significant ecological impacts. However, when their impacts are considered in the aggregate and/or examined within the context of the project's entire lifespan - including the potential for additional developments which may be induced - the results may be very different.

In addition to smaller-scale and less intensive activities, additional large resource development projects and undertakings - for example, mining and industrial forestry - remain a possibility for adjacent less-protected and unprotected lands. Yet these areas are also subject to the incremental impacts associated with small, independent developments. As such, the use of cumulative effects assessment is just as important for these areas. This is especially evident given the fact that resource development outside of the core protected areas will be more extensive as well as more intensive than inside and will, therefore, likely have more significant and far reaching impacts.

7.2.6 Discussion

If the five goals of ecosystem management identified by Grumbine (1994) are used as a basic framework for management of the greater St. Elias region, then the most important implication apparent here is the need to maintain the region's largely natural state and high degree of habitat connectivity to the greatest possible extent and incorporate the consideration of broad-scale ecological patterns and processes into planning and management. This is fundamental to maintaining viable populations and ecological and evolutionary patterns and processes such as the wildlife migration, species dispersal, and metapopulation dynamics described in Chapter Six. Moreover, given the widespread impacts associated with piecemeal development evident in more populated regions of North America, it is important that decisions on development within the region do not occur in isolation of one another and that cumulative impacts be considered.

Ultimately, from an ecosystem-based management priorities perspective, there is a greater need to integrate management and coordinate cooperation between the four core protected areas and their surrounding less protected and unprotected lands than there is to integrate management and coordinate cooperation with each other. This is especially evident given the fact that the surrounding unprotected lands are the areas where many of the threats to the integrity of the protected areas are likely to originate. Furthermore, as will be discussed in Section 7.5, there is a definite need to extend cooperation beyond the level of government to include all stakeholders, whether they be NGOs or individuals. In light of this conclusion, the following section examines specific foci for fostering ecosystem-based management between protected areas and their surroundings.

7.3 FOCI TO FACILITATE ECOSYSTEM MANAGEMENT

As stated in the introduction to this chapter, the biophysical synthesis carried out for this study supports a more process-oriented approach to incorporating regional ecology into integrated management of the St. Elias. Yet, given the size of the region as well as the number and diverse levels of managerial agencies involved, there is a definite need to establish some tangible areas for ecosystem management - even if these areas have “soft” or “fuzzy” boundaries.

Determining the size and location of such areas is the logical question that emerges here. Kenton Miller (1996) coined this process “balancing the scales” and asserted that such an area “must be large enough to maintain the integrity of the region’s biological communities, habitats and ecosystems, and to include the human communities involved in its management and use. Yet it must be small enough for residents to call it home and feel a sense of connection to its entire area.” The five areas discussed in this section are recommended as foci for fostering ecosystem-based management of the parks and protected areas of the greater St. Elias region. The regional biophysical and institutional syntheses as well as the regional ecological characterization were used as the fundamental basis for identifying these areas and Miller’s notion of “balancing the scales” was used as the guiding principle.

Despite the fact that they are considered separate entities, the five recommended partnership areas overlap somewhat. Given the size of the region and the number of management stakeholders involved this is unavoidable. Yet, at the same time, it is also quite advantageous as it reinforces the fact that they are each components of a greater St. Elias bioregion which experience similar, and at times related, issues related to resource use and development.

7.3.1 PWS-Copper River and Glacier Bay Ecosystems

In 1994 the US Department of the Interior selected twelve areas from across the United States where multi-agency partnerships would be forged to explore new ways to prevent environmental problems through cooperation and collaboration (Geisleman and Oakley, pers. comm., 1997). Two of these were located in Alaska: the Prince William Sound-Copper River ecosystem and the Glacier Bay ecosystem. Each of the projects are directly relevant to this study and are discussed here as they relate to future ecosystem-based management in the St. Elias region.

Both the Prince William Sound-Copper River (PWS-CR) ecosystem partnership and the Glacier Bay ecosystem partnership (GBEP) were officially formed in 1997 by way of formal memorandum of understandings (MOUs) signed by organizations with major natural resource management responsibilities. This included Wrangell-St. Elias NPP and Chugach National Forest in the PWS-CR region and Glacier Bay National Park and Preserve and Tongass National Forest in the GBEP. The specific purpose of each partnership is to "promote and facilitate communication, education, understanding, research, and cooperation to achieve an ecosystem perspective for the use and management of natural, cultural, and other resources" (Geisleman, 1997; Oakley, 1997). The two partnerships also share very similar goals, summarized here as:

i. Improve and actively maintain good communications among partners;
ii. Identify opportunities to meet common objectives;
iii. Gather and share information about natural, cultural and other resources and uses;
iv. Identify issues and information needs and cooperate to fill information needs;
v. Involve communities within the region in the identification of ecosystem issues, the interchange of information, and the collection of data; and
vi. Promote education to achieve better understanding of the issues, resources, and ecological relationships in the region.

The Biological Resources Division of the USGS Alaska Science Center coordinates and funds both ecosystem partnerships. Initiatives of both partnerships to date have been very similar, focussing primarily on information management and dissemination and facilitating regular communication. This has included creation of an integrated GIS database for each area, resource bibliographies, newsletters, and meetings between MOU signees.

Both the PWS-CR and Glacier Bay ecosystem partnerships are well suited as foci for strengthening ecosystem-based management of the St. Elias Mountain Parks - specifically Wrangell-St. Elias and Glacier Bay National Parks and Preserves, as well as the Tongass and Chugach National Forests. They are both established entities and they each have the support of the major American resource management agencies of the St. Elias region. However, several adjustments must be made to the two initiatives if they are to be successful in the future. First, each of the two projects requires sustained funding. Nineteen-ninety-seven represented the last year of the projects' initial four year funding. Subsequent years are now funded on a year-by-year basis, creating a great deal of uncertainty with respect to the projects' future. Originally it was hoped that as the BRD - considered a neutral party in the partnerships - gradually withdrew from directing the projects, the remaining agencies would step up to the task of coordinating the initiatives. Yet this has not been the case, and the initiatives appear to be "losing steam". Attendance at multi-agency meetings has experienced a gradual decline since their inception and resource managers responsible for making decisions are no longer attending meetings but, instead, sending staff representatives in their place. Clearly the various members of the partnerships need to recommit themselves to the projects. A revised MOU reaffirming the commitment of the various agencies may be required. Finally, an increased effort should be placed on collaborative projects and cooperative management. To date, each initiative has focussed primarily on information collection and dissemination and facilitating communication. Yet without a more significant level of interagency cooperation, the two projects run the risk of being known only for having been cooperatives which were brought together to create integrated geographical information systems, rather than to foster integrated management.

Two additional project-specific recommendations are worth noting. First, the PWS-CR ecosystem partnership should expand to include Kluane National Park in discussions and communications. Kluane need not be a signee to the MOU, but the eastern headwaters of the Copper River watershed do transcend the international border. Environmental change, particularly as a result of global warming, may necessitate more active involvement of Kluane in the future. Second, serious consideration should be given to consolidating the Glacier Bay ecosystem partnership with the Glacier Bay-Admiralty Island Biosphere Reserve, or at least clearly differentiating the two. Both initiatives are quite compatible, yet in many ways redundant. Formal discussions between the NPS and NFS are required to clarify this situation.

7.3.2 Greater Kluane Ecosystem

The biophysical characteristics of Kluane National Park suggest a greater requirement for transboundary ecosystem management than any of the three other core parks of the St. Elias region. The fact that all of the park’s viable habitat occurs within a narrow band adjacent to its northern and eastern boundaries (the “green belt”) cries for transborder management cooperation. The development of a coordinated multiagency greater Kluane ecosystem partnership is seen as definite requirement for fostering ecosystem-based management in the St. Elias region. Yet, given the American ecosystem initiatives described above, Kluane lags behind Wrangell-St. Elias and Glacier Bay National Parks in developing this type of multiagency partnership. Instead, Kluane has focussed efforts mainly on internal planning and management - primarily through development of park management plans and the establishment of the Park management board and renewable resources councils as a result of first nations land claim settlement. Some of this inward focus has come at the expense of excluding itself from opportunities in participating in collaborative projects. The most apparent example here is the development of the Greater Kluane Land Use Plan (GKLUP).

Kuhn and Duerden (1996) review the process of developing the GKLUP and characterize it as a means of providing “a comprehensive and locally accountable framework for land use planning” in the southwest Yukon (Kuhn and Duerden, 1996, pg. 64). As detailed in the plan itself, the purpose of the GKLUP was to “describe the ways in which land is used in the region, outline the concerns of residents about land use in the future, identify current and possible future land use problems, and chart a course of action towards sound land and resource management” (YTG, 1992, pg. 1). Yet, despite the fact that Kluane National Park occupies roughly one third of the region, Parks Canada largely abstained from the planning process, instead focussing efforts on updating its own management plan.

While the Greater Kluane Land Use Plan was completed in 1991 and revised in

1992, it has yet to be ratified by the Yukon Territorial Government and the Champagne and Aishihik First Nations are the only level of government to have fully endorsed it. In light of this, recent meetings regarding the future of the plan and discussions about its revision have taken place. Given this renewed interest, it is recommended that Parks Canada take a more active role in whatever revisions occur to the plan and strive to have Kluane National Park better represented in the plan. Depending on the extent to which this occurs, the GKLUP may or may not take the place of the greater Kluane ecosystem partnership recommended above, but it would at least provide the best available forum for Parks Canada to participate in influencing land use planning in the southwest Yukon.

7.3.3 Tatshenshini-Alsek Watershed

The biophysical synthesis in Chapter Five and the regional analysis of Chapter Six clearly illustrate the importance of the Tatshenshini and Alsek River corridors in the patterns and processes of biodiversity expressed in the St. Elias region. Not only are these two rivers critical components of the Tatshenshini-Alsek Wilderness Provincial Park, but they are also important to Glacier Bay National Park and Preserve, Tongass National Forest, Kluane National Park, Kluane Wildlife Sanctuary, and unprotected lands in British Columbia and Yukon. In short, these two river corridors are the threads that bind these areas together and each of the agencies responsible for managing these areas has a valid stake in their management.

While the Alsek River watershed overlaps the bounds of the Glacier Bay Ecosystem Partnership and the Greater Kluane land use planning area, it is significant enough to warrant specific attention in the form of multiagency collaboration. To this end, it is recommended that an international committee with representatives from a variety of stakeholders be established to examine the potential for an international river-use management plan. Experience with the efforts to prevent the Windy Craggy mine and establish the Haines Triangle as a protected wilderness suggest that this type of collaboration is quite feasible. Moreover, discussions with personnel from several different agencies suggests that most would be quite agreeable to such a forum and have, at least privately, considered such an international approach.

7.3.4 The Four National Parks and Equivalent Reserves

Despite a recommended emphasis on the above four undertakings, cooperation among protected areas is still paramount to achieving the goals of ecosystem-based management at a regional scale, particularly since these are the areas most likely to support the highest level of ecological integrity. Moreover, given that the four core protected areas share remarkably similar management objectives, the question begs asking: if these areas cannot serve as a model for coordinated interagency cooperation, which can? This provides the impetus for the next section.

7.4 TOWARD IMPROVED INTERPARK COOPERATION

There is very little in the way of conflicting land use between Kluane National Park, Tatshenshini-Alsek Wilderness Provincial Park, and Glacier Bay and Wrangell-St. Elias National Parks and Preserves. Each of these areas have similar management goals and objectives based on preservation. Given the similar management objectives identified for the four areas, it seems as though cooperation between the four parks would be natural. Yet, as illustrated in Figure 7.2, cooperation and coordination of activities is limited primarily to informal communication - particularly across the international border. In light of this, this section attempts to answer the following three questions: (i) what are the factors that have limited cooperation in the past?; (ii) how can these factors be overcome to improve cooperation?; and, (iii) what approaches can be used to improve transborder cooperation?

7.4.1 Obstacles To Cooperation

There are several reasons why cooperation between the four core protected areas is not more prevalent. Certainly, as the results of the regional biophysical synthesis indicate, there are areas where interpark cooperation - at least on biophysical grounds - is unnecessary. Yet, there are areas where cooperation appears justified but is absent or lacking. Apparent reasons for this are described here.

Firstly, planning and management in the region is primarily issue driven and the need for cooperation is not seen until a specific issue arises. This is an approach commonly observed in resource management, and while it may be suitable for minor "day-to-day" problems, it is poorly suited for issues of regional significance. Secondly, while they may realize the importance of cooperation, the priority of land management agencies is to their own lands. Often resources, funding, and staffing are strained enough as it is and increasing the level of interagency cooperation is perceived as extraneous to meeting

Figure 7.2:
Direct Cooperation Between Parks of the St. Elias World Heritage Site

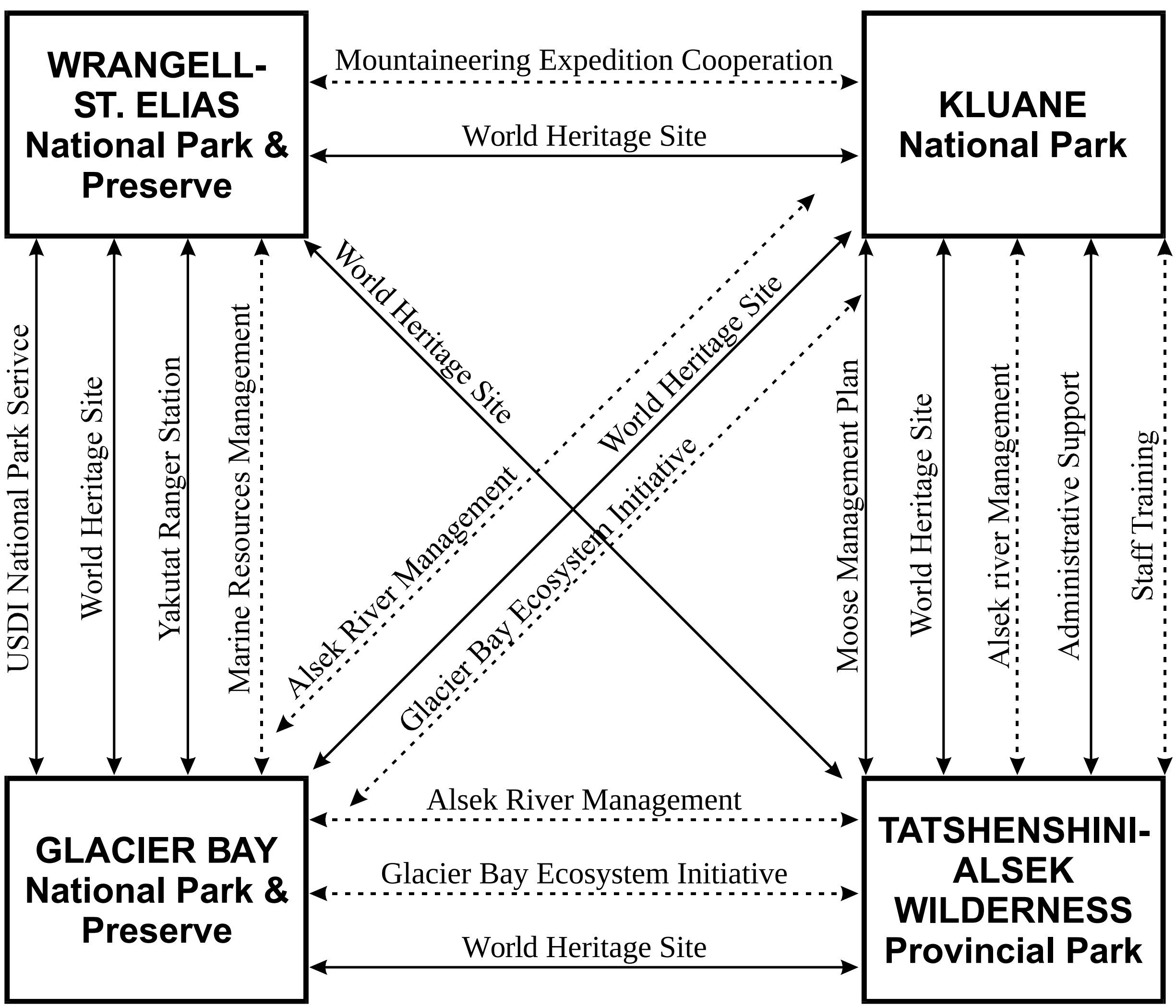
Key

Formal Agreement

Informal Agreement

Note

Communication and information sharing is categorized under the World Heritage Designation



specific management objectives. This perception is not surprising given the size of the St. Elias region and its parks and protected areas.

While management cooperation between the Canadian and American elements of the St. Elias region does occur, it is apparent that it is not nearly as extensive as that between agencies of the same nation. The reasons for this are varied and numerous. One of the factors hindering cooperation between the two American national parks and the Canadian parks is the lack of staff equivalents in the area of resources management. Rangers in the American parks and wardens in the Canadian parks are roughly equivalent. However, resources management staff in the US parks, such as zoologists, botanists, environmental analysts, etc., have no direct equivalents in the Canadian parks. Instead, Canadian equivalents work out of regional offices and Canadian wardens are required to fulfill "double duty" and undertake activities related to both resources management and visitor services. Conversely, staff in US national parks change so often that it is difficult for them to establish any cooperative relationships with Canadian wardens, regardless of whether or not there is an equivalent position.

Finally, and perhaps most significantly, there is a perception among some government representatives that increasing cooperation somehow means relinquishing control. As discussed in Chapter Two, such a perception has been observed in other transborder park situations and acts as a substantial stumbling block in creating formal agreements between parks. Alaskan parks are reluctant to increase the amount of activities carried out under the flag of the world heritage or biosphere reserve designations because of a general statewide apprehension towards these international designations, and the original decision to stop short of joint management between Kluane and Wrangell-St. Elias appears to have been made by Canadian government officials who felt that such an approach would not concur with popular nationalistic feelings at the time (DOS, 1972). More recently, Alaska representative Don Young has introduced an *American Land Sovereignty Protection Act* to Congress to curtail US participation in UNESCO's World Heritage Convention and Man and the Biosphere program, charging that such programs are "United Nations experiments within sovereign US borders" (Baker, 1996).

7.4.2 Fostering Improved Cooperation

Overcoming these hurdles is an important step in improving interpark cooperation and taking a step towards integrated management of the region. At the international level this relates to increasing trust between the two nations. Canadians are typically fearful of having their identity absorbed by American culture, and Americans tend to be weary of relinquishing any control on issues of international nature. Overcoming these broader, almost philosophical, obstacles must involve the recognition by each nation of the other's concerns and efforts to improve cooperation must be accompanied with assurances that working together will not lead to a loss of identity or liberty.

Transcending the binational nature of the St. Elias are the First Nations that call the entire region home. The interconnected cultures of these peoples span both spatial and temporal boundaries, as well as the permeable boundaries between the biophysical and cultural environments, thereby providing what is perhaps the most comprehensive regional linkage of all. On an ideological level many of the these peoples consider themselves citizens of North America rather than Canada or the USA. First Nation peoples could play a significant role in bridging the international border, helping to reduce some of the broader obstacles to international cooperation and bringing Canadian and American agencies closer together for mutual benefit.

Overcoming obstacles to international cooperation at a more local level includes reinforcing the general benefits of cooperation, building consensus among agencies, identifying common goals and objectives, and identifying shared resources. Recognizing and building upon commonalities appears to be the most important step in fostering improved interpark cooperation as regional integration of these areas. For purposes of discussion, these commonalities can be divided into two categories: shared resources and common issues. The biophysical resources shared by the parks are thoroughly described throughout the synthesis of Chapter Five and are further articulated in the analysis of Chapter Six. These resources and the activities carried out in their management certainly provide a focus for improving interpark cooperation. As an example, species inventories and status assessments, monitoring of specific wildlife populations, and mapping and analysis of vegetation communities are activities common to each park. Each of these could be coordinated under a multi-park initiative aimed at analysis and assessment and management of biodiversity within the four parks. Experience and information could be shared, methods and data standardized, and future tasks coordinated, shared, and even integrated. Given the commonalities in each of their physical environments, a similar approach involving geology, physiography, climate, glaciers, hydrology and water resources is also feasible. Universities and government research agencies could be a valuable component of such collaboratives, providing research and monitoring expertise as well as assisting in attaining and sustaining additional funding.

Not described in this thesis, but also shared by the four parks, are historical and cultural resources related to a common regional heritage including occupation of the area by First Nations for thousands of years; early exploration of the region along coastal and interior routes; mountaineering, scientific research, and modern exploration; settlement of the region during the 19th and early 20th centuries; and mineral exploration over the past 150 years. Relics of this shared heritage exist throughout the region, ranging in age from prehistoric archeological sites to abandoned mines and mills. This common heritage and its existing relics are additional resources that transcend the international border and provide an additional foundation for fostering interpark cooperation and coordination.

As detailed in Chapter Four, the four St. Elias Mountain Parks were established for similar reasons, permit similar levels of use and provide similar levels of protection, and are experiencing similar management issues and concerns. In combination with the fact that each area is managed with the same overall objective in mind (i.e. preserving wilderness and ecological integrity), these commonalities certainly act as a broad foundation for coordinated cooperation between the four parks. Sharing resources and expertise and drawing on common experiences can only improve planning and management in the four parks and could assist in resolving transboundary issues.

There are numerous cases where the same management problem or issue experienced in one park is the same as, or similar to, that experienced in the others. For example, each of the four parks have experienced an infestation of spruce bark beetle in the past several years. Kluane and Wrangell-St. Elias have each faced local criticism for allowing this natural process to occur because of the potential for it to spread to adjacent unprotected forests, the increased potential for fire in infested areas, and the loss of economically valuable timber. Each of the two parks has undertaken significant programs in research and monitoring as well as public outreach to assist in related resource planning and decision making. The experiences in these two parks should be shared with each other as well as with Glacier Bay and the Tatshenshini-Alsek where outbreaks could lead to similar debate.

Visitation in the form of both backcountry and frontcountry use is increasing throughout the region, and similar demands associated with this increasing use are faced by each of the four core parks in the region. These include pressure to increase and/or improve roads, trails, and visitor facilities, as well as demands for expanding the range of activities permitted within the parks. The dual nature of parks and protected areas and the preservation vs. use conflict this creates is certainly not unique to the St. Elias region. Yet, given that the four parks are experiencing analogous situations, there is an obvious opportunity for cooperation in the form of improved communication and collaboration.

Less immediate, but nevertheless significant, issues related to environmental change also illustrate potential foci for cooperation. For example, the need for cooperation in planning for climate change is particularly evident given the fact that each park has a significant portion of its area under ice. Yet the consequences of global warming on the park environments has received surprisingly little attention given its potential impacts on not only the physical and biological environments, but also human use and occupancy of the region. Clearly there is an avenue here for joint funding of research and collaborative monitoring.

These foundations for fostering improved cooperation certainly extend beyond interpark cooperation and are applicable to the efforts necessary in integrating management of the parks with their less protected and unprotected surroundings. Yet, as noted above, the four parks of the World Heritage Site provide a fertile ground for cooperation because of their common purpose and management objectives as well as associated common issues.

Overcoming barriers related to time and resources is difficult, especially in times of fiscal restraint. Yet there are real opportunities here for collaboration and cooperation that could be cost effective both over short and long terms. Strengthening relationships in the absence of major issues can assist in preventing such problems from arising or having smaller issues erupt into much larger ones (Gray, 1992). The advantages associated with economies of scale are perhaps the most apparent benefit of cooperation in the short term given the potential for improved cooperation to save money through the sharing of resources and expertise as well as reducing in the duplication of tasks. Yet, while it is these monetary benefits that may provide immediate rationale for improving and coordinating cooperation, the broader benefits associated with creating an example of international cooperation that other regions can look towards should not be overlooked.

7.4.3 Approaches for Coordinating Interpark Cooperation

The four core St. Elias Mountain parks have formally recognized the need for international cooperation in their respective management plans. The Wrangell-St. Elias General Management Plan (NPS, 1986) states that "the National Park Service will continue to work cooperatively with Parks Canada at Kluane National Park on search and rescue, resource management, visitor information, and other areas of concern". Even before its inclusion in the world heritage site, Glacier Bay's management plan asked "How should management direction for backcountry use, resource management and river management be coordinated with other state and federal agencies and with the Canadian government?"(NPS, 1984). Finally, the Kluane National Park Management Plan commits the park to cooperation with the US National Park Service by stating that "cooperation with United States National Park Service authorities for the joint UNESCO World Heritage Site will be continued"(Parks Canada, 1990). Each of these statements reinforce the fact that the agencies responsible for the four parks recognize the importance of participating in management cooperation with their international neighbours.

Given some of the barriers to cooperation that were described previously, the key to successfully improving interpark cooperation in the near future is to ensure that coordinated planning and management is carried out at a level which best serves the common objective of the four parks (i.e. preservation of wilderness character and qualities) without jeopardizing jurisdictional sovereignty. At one extreme, this could mean the formation of a broad alliance between the four parks. This could entail the sharing of resources, staffing, and facilities; joint programs in operations, monitoring, resources management and scientific research; and shared features in visitor management and operations such as complementary interpretive programs.

Such an alliance would be complex in nature and likely require a formal umbrella management plan and management board as well as an international agreement to guarantee commitment to the park. In turn, it is probable that such complexity and formality would detract from its desirability as a method of improving cooperation. However, the individual components outlined above could certainly exist independent of the alliance.

At the other end of the spectrum is the task of simply improving communication. At the very least, the four parks of the St. Elias should undertake communication and information sharing with each other on a regular and more frequent basis. Similarly, meetings between park managers and/or staff should also occur on a regular and more frequent basis.

One definite - and easily attainable - objective that should be pursued by the four core parks is the development of a common interpretive program to educate visitors about the linkages and resources shared by the parks. This could include common interpretive themes and programs (e.g. World Heritage status) as well as joint publications. Experience with this type of collaboration in other transborder protected areas has been quite positive (Hamilton *et al.*, 1996). In fact, some thought has already been given to this notion. A preliminary meeting was held in 1997 between the four parks to discuss the possibility of coordinating interpretive programs and the Champagne and Aishihik First Nation has suggested giving the world heritage site a single name and logo (Chambers, pers. comm., 1997). Chapters Five and Six of this thesis could provide a strong foundation for the development of this interpretive program and could provide useful insight in the process of identifying a name that characterizes the entire region.

There has been longstanding discussion about the possibility of having Kluane, Wrangell-St. Elias and nearby areas designated a biosphere reserve (Parks Canada, 1990; YDRR, 1990; Slocombe, 1992). This designation and associated managerial framework appears to have promoted cooperation in other transboundary protected areas (Danby, 1997) and the entire St. Elias region already has a zoning structure similar to that of biosphere reserves. However, as exemplified by World Heritage status, assigning an international designation does not necessarily ensure success. While World Heritage status has certainly promoted communication and coordination of some activities between the St. Elias mountain parks, it is probable that this level of cooperation would have occurred regardless of the UNESCO designation. Instead, a true commitment must be made to work towards common goals and objectives. If designating the St. Elias region as a biosphere reserve would ensure commitment then it should, perhaps, be considered. However, given that the region already expresses characteristics of a biosphere reserve (i.e. protected core with buffer areas), it is the managerial approach which needs refinement.

International cooperation in resources and environmental management is often reactionary and single-issue based. However, there is a real opportunity in the St. Elias to take a different approach. Improving cooperation between the St. Elias Mountain parks now could act to prevent problems from arising in the future. The basis for such cooperation already exists - in the form of a United Nations designation of the area as a World Heritage Site, in the form of a transboundary ecosystem of global significance, and in the form of one of the most peaceful bi-national relationships in the World.

7.5 BEYOND INTERGOVERNMENTAL COOPERATION

As mentioned earlier, this thesis has intentionally focussed on the managerial relationship between government agencies primarily because of the dominant nature of this sector in environmental and resources management in the St. Elias region and the north in general. Given this focus, much of the discussion to this point has centred on the need for improving cooperation between these agencies. Yet there is an equally compelling need for cooperation to occur between government agencies and nongovernmental stakeholders including First Nations, public interest groups, private citizens, and industry. As discussed in Chapter Four, the involvement of some of these groups in cooperative relationships with government agencies already exists to some extent and, as discussed by Slocombe and Danby (1998), local cooperation, participation and consultation between government and nongovernmental stakeholders seems to be increasing throughout the region. However, involvement of these groups in the planning and decision making process must be actively sought, and the need for it specifically recognized - particularly if regional integration of the parks and protected areas of the St. Elias region is to be successful.

First Nations are a particularly interesting case in the St. Elias region, as they appear to straddle the gap between government and nongovernment agencies. With the settlement of aboriginal land claims in the Yukon and Alaska, First Nations have significantly increased their level of involvement in land-use planning and resources management. In the Yukon, First Nations now constitute a unique level of government with a legislated right to participate in environmental and planning and management. In Alaska, First Nations are legal corporations with substantial landholdings and political influence.

Particularly relevant from a First Nations viewpoint is the need to incorporate indigenous or traditional knowledge into management and decision making. Strides are being made with respect to the documentation of such knowledge in Yukon, Alaska, and British Columbia through community-level mapping projects and transcription of oral histories. The formal use of this information in land use planning and management is increasing, particularly as the role of First Nations in decision-making increases (Kuhn *et al.*, 1994).

The notion of involving all interested and affected parties in working towards regional integration of the parks and protected areas of the St. Elias region is clearly an avenue for future work. At a broader level, much of this is related to a movement away from the conventional rational or managerial planning approach towards a more pluralist approach (Nelson and Serafin, 1996). As Nelson and Serafin (1993) assert in describing the civics model, such a movement "underscores the importance of actively involving those who must bear the costs and benefits of environmental decision making" (pg. 393). Although the application of such a model to the St. Elias region is far beyond the scope of this thesis, at least this much is evident here: identifying nongovernment stakeholders and actors should be a priority for each of the five proposed areas for integrating management cooperation, as should the development of frameworks for their involvement.

7.6 SUMMATION

Prior to undertaking this study, it was anticipated that an integrated approach to managing the entire St. Elias region might be warranted and that Kluane, Wrangell-St. Elias, and Glacier Bay National Parks, along with the Tatshenshini-Alsek Wilderness, should be viewed as - and therefore managed as - one single core protected area. While this notion still has a certain degree of validity, the results of the biophysical synthesis and ecological analysis also suggest that these areas have equally as many differences as they do similarities and integrating management of these parks with their less protected and unprotected surroundings is actually of greater importance with respect to maintaining ecological integrity across the region.

In light of this conclusion, five overlapping areas have been recommended here as foci for fostering and ecosystem-based approach to management and integrating management of the four core areas with their surroundings. Based on their institutional and biophysical environments, these areas appear to be ideally suited for this purpose. Yet the fact that they overlap to a certain extent actually necessitates their interaction and reinforces the fact that they are each components of a greater St. Elias "bioregion" which shares similar - though perhaps separate - issues related to resource use and development.

CHAPTER EIGHT
SUMMARY AND CONCLUSION

8.1 SUMMARY

The St. Elias region comprises a network of public lands and protected areas managed by a variety of federal, state, provincial, and territorial agencies. Four areas constitute its protected core: Wrangell-St. Elias National Park and Preserve and Glacier Bay National Park and Preserve in Alaska, Kluane National Park and Reserve in the Yukon Territory, and the Tatshenshini-Alsek Wilderness Provincial Park in British Columbia. These four parks span a total combined area of 98,300 km^2. Two congressionally legislated Wilderness areas in Alaska's Tongass National Forest - Russell Fiord and Endicott River - add another 1,811 km^2 to this contiguous protected area. Finally, Tetlin National Wildlife Refuge in Alaska adds an additional 3,739 km^2 to the total area, rounding out what is the second largest contiguous protected area in the world. Specially managed areas - the Kluane Wildlife Sanctuary in Yukon, and the Chugach and Tongass National Forests in Alaska - add further to this transborder protected area.

The primary goal of this thesis was to characterize the regional ecology of St. Elias region and, in turn, provide some assessment of the implications this has for its management - particularly as it relates to cooperation between parks and protected areas and adjacent unprotected lands. Several objectives were identified to assist in meeting this goal:

i. Compile an extensive database on the biophysical nature and institutional setting of the St. Elias Region and build this database into an integrated geographical information system (GIS);

ii. Identify and describe existing cooperation and coordination between protected areas and surrounding land agencies in the St. Elias Region as well as shared management objectives and common management issues;

iii. Generate a regional biophysical synthesis of the St. Elias through integrative mapping and analysis for the purpose of identifying similarities and differences within the region as well as shared ecological features and processes and key linkages between its protected areas and adjacent lands; and,

iv. Analyze the synthesis with a view to assessing the biophysical basis for coordinating intergovernmental cooperation within a framework for ecosystem management - particularly as these activities relate to the conservation of biodiversity and maintenance of ecological integrity.

A methodological process loosely based on the ABC resource survey method (Nelson *et al.*, 1988) was used to meet these objectives and the fields of conservation biology and landscape ecology provided theoretical foundations for analysis. The following subsections summarize how these four goals were met and the conclusions which were made.

8.1.1 Database Compilation and GIS Creation

The compilation of ecological data and information on the St. Elias region occurred primarily by way of two intensive field sessions during the summers of 1997 and 1998, preceded by a shorter “reconnaissance trip” in December 1996. Library and database searches combined with interviews with key agency personnel and regional stakeholders were the primary methods used. Given the volume of information available, its widespread nature, and the multidisciplinary nature of the study, it was impossible to review all available information. However, a significant effort was made to review and collect as much relevant information as possible, especially as it related to the specific themes of the synthesis.

Information was synthesized in three distinct fashions. The first, and most straightforward, was the synthesis of textual information. The creation of tables or matrices acted as the second tool in synthesizing information. The creation of a regional GIS was the third - and most complex - method of synthesis. MapInfo was used in this task because of its ease of use in digitizing maps as well as the fact that its data is transferable to virtually all other GIS and desktop mapping software packages. The approach utilized in building the GIS was modelled after Aberley's (1993) method for bioregional atlassing where emphasis is placed on region-wide properties and trends as opposed to specific local components. The various institutional, physical, and biological thematic layers were created from the compiled database primarily by way of manual digitization and data entry.

8.1.2 Existing Interagency Cooperation

Interagency cooperation in the St. Elias region was modeled using a relative scale based on formality and complexity. In summary, the results of this modelling indicate a relationship between the formality and complexity of interagency cooperation. Generally, complex interagency cooperation is accompanied by formal agreements while informal agreements are most often used in situations with few actors or less serious management issues. Most interagency cooperation in the St. Elias region is informal in nature and occurs between individual land management agencies. Cooperation is significantly less frequent between Canadian and American agencies.

Based on common characteristics, cooperative efforts in the St. Elias region can be grouped into five general categories. General *communication and information sharing* between agencies sharing a particular resource is the most common type of management cooperation, and is the least formal and least complex of the five categories. *Coordination and collaboration* represents the next level in management cooperation. This is an extensive category that is comprised of a wide variety of cooperative relationships like activity coordination, joint programs, collaborative research and monitoring, and infrastructure and resource sharing. *Cooperative management* is the third level of cooperation. Cooperative arrangements in this category are normally directed by a formal agreement between two or more resource management agencies and may include involvement of end users/user groups or special interest groups. The fourth category, *joint management*, is the most formal and complex. This type of interagency cooperation places a heavy reliance on one or more formal agreements to maintain a very specific arrangement. These agreements are very intricate and detailed in nature, and often have independent budgets established for their administration. The final category, *international agreements*, refers to cooperative relationships that have been initiated outside of the St. Elias region. They are directed by formal agreements to which the United States and Canada are signees and, therefore, to which management agencies in the St. Elias region must adhere.

Examination of institutional arrangements for managing the St. Elias region indicates that the need for cooperation and the benefits obtained from it are widely acknowledged and recognized. Yet, analysis of the experience with cooperation in the region suggests that a more integrated approach to resource planning and management would assist in reducing the difficulties associated with the fact that numerous agencies share management of the same resource or portions of the same ecosystem. Furthermore, such an integrated approach would provide a suitable framework within which coordination of intergovernmental cooperation could occur. Several existing collaborative initiatives provide a foundation upon which such an approach could be built.

8.1.3 Regional Ecology

As the third objective of this study states, the regional biophysical synthesis was carried out to identify shared ecological features and processes and key linkages between protected areas and adjacent lands. For the most part, the information, data, and maps presented as part of this synthesis represent the first time similar biophysical information from across the entire region has been combined. The regional ecological analysis that followed the synthesis aimed to assess the relative degree to which the region is interconnected - that is, the extent to which the entire area behaves as a coherent unit.

The results of the synthesis and analysis illustrate numerous regional-scale ecosystem components that are shared throughout the entire St. Elias region. Perhaps most significant among these from a conservation ecology viewpoint are populations of large mammals and other species of wildlife which are, in most cases, naturally regulated;

intact watersheds with largely natural stream flow dynamics; and vegetation communities and/or plant associations that experience a full suite of natural disturbances with relatively little human intervention. Also identified are linkages between specific areas of the St. Elias region, including the valleys of the Tatshenshini, Alsek, and Copper Rivers which serve as links between coastal and interior areas; low elevation valleys which run out of the central mountainous areas and act as movement corridors for wildlife and carry runoff from the valley glaciers extending from the central icefields; and less tangible and more variable links such as wildlife metapopulations and transboundary vegetation communities and ecosystems.

Despite these shared characteristics, linkages, and ecological influences, the St. Elias cannot really be viewed as constituting a single, coherent region. Results of the biophysical synthesis and ecological analysis indicate that there are equally as many differences between the parks and protected areas, and that these areas are just as closely linked with surrounding unprotected areas. The mountain barrier between coastal and interior areas, as well as the icefields that form the heart of the region are the two primary reasons for these differences. Climatic conditions are so different on either side of the coastal mountain barrier that completely different ecosystems predominate. Further, the icefields of the St. Elias Mountains are so formidable and conditions so harsh that they create a virtual wall to the movement of biota.

8.1.4 Management Implications

The end result of these ecological similarities and differences is that the greater St. Elias region actually represents the point at which several different regional-scale ecosystems converge, rather than one single, coherent region. In light of this, it is difficult to define a single and distinct boundary for collaborative management that includes each of the region's parks and protected areas. Instead the greater ecosystem of each protected area is different from that of the others; even though it may contain a portion of - or all of - another protected area. Rather than a predefined regional boundary, the regional ecology of the St. Elias Mountain Parks seems to advocate a more process-oriented approach to management wherein the development of a coordinated set of principles, goals, and objectives to guide planning and management is more important than defining specific management boundaries.

Given its overall goals of maintaining ecological integrity and sustaining biodiversity and ecosystem processes at a regional scale, ecosystem management is ideally suited for the parks and protected areas of the St. Elias region. Five broad goals and objectives of ecosystem management are often identified:

i. Maintain viable populations of all native species in situ;
ii. Represent, within protected areas, all native ecosystem types across their natural range of variation;
iii. Maintain evolutionary and ecological processes;
iv. Manage over periods of time long enough, and across spatial scales large enough, to maintain the evolutionary potential of species and ecosystems;
v. Accommodate human use and occupancy within these constraints.

After examining these five objectives within the context of the greater St. Elias region's biophysical and institutional environment, several broad management implications can be identified. The most significant of these is the need to maintain the region's largely natural state and high degree of habitat connectivity and incorporate the consideration of broad-scale ecological patterns and processes into planning and management. This is fundamental to maintaining viable populations and ecological and evolutionary patterns and processes such as wildlife migration, species dispersal, and metapopulation dynamics. Moreover, given the widespread impacts associated with piecemeal development evident in more populated regions of North America, it is important that decisions on development within the region do not occur in isolation of one another and that cumulative impacts be considered.

Five foci are recommended to act as frameworks to coordinate and improve the intergovernmental cooperation which is necessary to work towards ecosystem management in the St. Elias region:

- Prince-William Sound - Copper River Ecosystem Partnership
- Glacier Bay Ecosystem Partnership
- Greater Kluane National Park Ecosystem Collaborative
- Tatshenshini-Alsek Watershed International Working Group
- St. Elias Mountain Parks

While the first two of these frameworks already exist, it is recommended that formal commitment by participating agencies be reestablished and that the agencies work toward elevating cooperation beyond the level of communication and information sharing. The second two frameworks do not yet exist, although variations of them have been conceived in the past. The final framework involves improving cooperative relationships between the four national parks and equivalent reserves. At one extreme, this could mean the four parks forming a formal alliance. At the very least however, this should involve improving communication between the four parks by way of frequent information sharing and regular meetings. One definite objective that should be pursued is the development of a common interpretive program and granting the World Heritage Site a single name which reflects the region's shared natural and/or cultural heritage. This thesis could provide a strong foundation for the development of this interpretive program and could provide useful insight in the process of identifying a name that characterizes the entire region.

Finally, extending management cooperation beyond the level of government to include all stakeholders in planning and decision making is seen as an important objective for each of the five recommended areas.

8.2 ASSESSMENT OF RESEARCH AND INFORMATION NEEDS

The synthesis of ecological information from a variety of sources and across formats is an integral component of environmental management. Yet, until recently, the final product of such syntheses was a static document which became outdated and/or rendered incomplete as new data and information was collected, and the task of updating these types of documents on a regular basis was not a viable option. Furthermore the large size and sheer volume of information generated through the process of information synthesis often limited their usability and the potential for information dissemination. However, with the continual advancement and increasing usability of personal computing technology this process is becoming less forbidding and more inviting. In light of this, a primary objective of this project was to create a dynamic database in the form of a GIS which is capable of continual and ongoing data and information addition, revisions, and updates.

As described in Chapter Two, a multidisciplinary resource-survey approach based on the ABC Method was adopted for use in developing the regional GIS. In general the process was well suited to the scale of this project, although at times - primarily because of its multidisciplinary nature - it resulted in the completion of needless and/or superfluous work. In hindsight, it might have been better to have focussed only on the theme of wildlife and/or biodiversity. This would have given the thesis a clearer focus and would have significantly reduced needless tasks. Yet, as the thesis has shown, the physical and biological components of the region are intertwined to such a degree at the regional level that it is difficult to discuss one in the absence of the other. Moreover, without this multidisciplinary approach, this thesis would not have been able to assess the total range of information currently available across the region.

By its very nature as a synthesis of available information, the process of completing this thesis has facilitated review of an abundant volume of information. In turn, the process of research and review also identified the areas for which there is no raw data or information available as well as for research problems and management issues for which no studies have been carried out. The following subsections provide a cursory assessment of the state of information on the institutional, physical, and biological components of the region and recommend areas where future research and studies are required.

8.2.1 Data and Information Availability

Certain areas within the St. Elias Region have long been centres of independent scientific research. Foremost among these are Glacier Bay, the Kluane Ranges and adjacent Shakwak Trench, and the Icefield Ranges. In addition, the presence of the protected areas and other publicly managed lands has resulted in the accumulation of considerable information on renewable resources such as forests and wildlife through monitoring and data collection. Further still, aboriginal peoples have inhabited portions of the region for thousands of years and have an unsurpassed familiarity and first-hand knowledge of many of its areas. In combination, these sources constitute a wealth of information. Yet, given the size and remoteness of the region, there are many areas where information is lacking or even nonexistent.

While data and information on the biophysical character of the St. Elias region is abundant, much of it is unconsolidated in nature, poorly accessible, and/or in formats unusable for the purposes of planning and management. Spatial data and mapping is mostly based on state, provincial, or territorial coverages and there are few examples, except at very broad scales (i.e. continental), of cross boundary integration. The one notable exception here is in the geological sciences where collaboration between the USGS (US Geological Survey) and the Geological Survey of Canada (GSC) has resulted in jointly authored publications on the geology of Alaska, Yukon, and British Columbia.

This unconsolidated nature is, however, changing with the improvement of data storage and analysis techniques and the use of GIS and remote sensing in the three national parks and by state, provincial, and territorial agencies. In fact, large strides are being made in the use of these technologies for accurately mapping vegetation communities at a fine scale; a product which is currently sporadic for the region. Much of the information available on wildlife is from monitoring undertaken by staff of protected areas or by state, provincial, or territorial departments. Because of this disjointed nature, however, similar information for the same species is not available for the entire region.

While not aggregated in any one document, or synthesized in any fashion, information on the human-institutional setting of the region is both detailed and abundant. Regulatory and management purposes provide the obvious rationale here and such information ranges from hunting and fishing regulations to legislated mandates for planning and management. Much of this information is included in the respective management plans for each protected area. However, outside of the two US national forests, information on land use has not been brought together in any systematic fashion and any land use mapping that has been undertaken lacks detail.

8.2.2 Information Needs and Suggestions For Further Research

Through the process of synthesizing such a large volume of information, the institutional and biophysical syntheses certainly helped to fill some of the voids noted above. Yet, the fact that a multidisciplinary approach was taken also means that focus on any one specific resource, resource group, or resource issue was avoided. It is therefore probable that details which are more relevant at a finer scale of analysis are absent here. In light of this context, the regional biophysical and institutional syntheses should be considered as starting points for future regional-scale and/or landscape-scale research and studies, rather than comprehensive entities. Table 8.1 provides a number of examples of specific themes for which this type of expanded synthesis should occur as well as additional research, monitoring, data-collection, and mapping which should be undertaken in various portions of the region.

Table 8.1: Additional Biophysical Monitoring and Inventory Recommended for the St. Elias Mountain Parks

Area	**Recommend Data Collection and Monitoring Projects**
Wrangell-St. Elias NPP	‣ Large carnivore research and monitoring (grizzly bear, wolverine, wolf, black bear) ‣ Fire ecology research and analysis ‣ Breeding bird and small mammal inventories
Glacier Bay NPP	‣ Vegetation community mapping
Kluane National Park	‣ Revised vegetation community mapping of park and all adjacent areas
Tatshenshini-Alsek Wilderness	‣ Vegetation community mapping ‣ Ungulate habitat and distribution mapping ‣ Large mammal research and monitoring ‣ Breeding bird, small mammal, and vascular flora inventories ‣ Spruce beetle monitoring and research ‣ River use surveys, research, and monitoring

There are large amounts of information and monitoring data on the individual physical and biological settings of the protected areas and managed resource lands of the St. Elias region. However, much of it is widely spread out amongst agencies. As such, in addition to the recommendations in Table 8.1, it is recommended that attempts continue to be made in consolidating physical, biological, and institutional information into a single document. Kluane National Park's "Resource Description and Analysis" (Gray, 1987) provides an excellent "one-source" synthesis of biophysical information on the park (although a revised edition is in order). Wrangell-St. Elias and Glacier Bay National Parks and Preserves, as well as the Tatshenshini-Alsek Provincial Park and the Tetlin National Wildlife Refuge would benefit significantly from the development of similar documents.

While there are numerous avenues of research that could be undertaken with respect to the five recommended ecosystem partnerships, two tasks are seen as basic components of each and, therefore, relevant to the entire St. Elias region. These are:

- Identify, categorize, and map human land use and ecosystem stressors; and,
- Identify, map, and inventory important habitat areas.

Each of these two tasks are seen as fundamental requirements to management of the St. Elias region. Given its multidisciplinary nature and regional focus, this study was not capable of this level of synthesis and analysis. However, carrying out these tasks at the scale of each of the recommended ecosystem partnerships would be a more manageable effort that would yield highly beneficial - and very usable - results.

8.3 CONCLUSION

The greater St. Elias region supports a highly diverse suite of species; healthy, naturally regulated populations of many large mammals; and physical processes that still continue with little interference from humans. These features and the processes that govern them still exist in the St. Elias region because of the size and extent of a protected area conglomerate that ranks second in the world in total area. The most important step in preserving these features and processes is to maintain - and even improve - the level of protection offered by these areas. Despite a trend towards broader, transborder, planning and management - much of which is endorsed here - core protected areas with preservation-oriented objectives are still fundamentally required as anchors in regional biodiversity conservation strategies.

However, an emphasis on maintaining and improving protection of the four national parks and equivalent reserves must not come at the expense of ignoring surrounding less protected or unprotected areas. Indeed, just the opposite should occur. Given that Kluane National Park, Tatshenshini-Alsek Wilderness Provincial Park, and Wrangell-St. Elias and Glacier Bay National Parks and preserves share ecological connections that are at least equally strong with surrounding areas as they are with each other, an improved level of cooperation between these management agencies must be fostered. Without an expansion of planning and management across their boundaries the four core areas run the risk of, in time, further isolating themselves from surrounding jurisdictions and even surrounding natural areas.

The ecological and institutional structure of the St. Elias region can provide valuable insight as to how to best approach large-scale biodiversity conservation strategies. Given that the phase of establishing protected areas in the region is likely complete, it can be instructive in assessing best approaches for managing large protected area networks and could serve as a valuable case study in developing integrated management plans for these areas. If other large-scale biodiversity conservation projects - such as Yellowstone to Yukon and Algonquin to Adirondacks - are to be successful, experience in the St. Elias region could play an instrumental role.

On a final note, despite the achievements that have been made in protecting the St. Elias region, the road ahead remains challenging. Wilderness has been contested on several fronts in the past several years. In addition to the more historical conflict between wilderness preservation and resource use, the very idea of wilderness has been criticized as "anachronistic, ecologically uninformed, ethnocentric, historically naive, and politically counterproductive" (Callicott, 1995 quoted in Noss, 1996). Yet, above all else, this study has shown that it is because of the total size and unfragmented nature of its wilderness that the St. Elias region retains such a high level of ecological integrity and remains as one of Earth's last great natural areas. Management rooted in the science of ecology and its principles - ecosystem-based management - is seen as an important method of assuring that this natural heritage lives on as a legacy to future generations.

APPENDIX A

GLOSSARY OF SELECTED TERMS

GLOSSARY OF TERMS

Allopatric: Living in different areas.

Anadromous: Refers to the characteristic associated with fish that typically inhabit seas or lakes but ascend streams to spawn.

Biodiversity: Defined by the Keystone Center (1991) as "the variety of life and its processes, including the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur, and the ecological and evolutionary processes that keep them functioning, yet ever changing and adapting."

Clade: A taxon containing a common ancestor and all the species descended from it.

Deme: A group of interbreeding individuals within a population, also known as a local population.

Ecoregion: "A continuous geographic area over which the macroclimate is sufficiently uniform to permit development of similar ecosystems on sites with similar properties." (Kaufmann *et al.*, 1994).

Edaphic: Pertaining to or relating to soil character and conditions.

Equilibrium Theory of Island Biogeography: A hypothesis put forth by McArthur and Wilson (1967) which explains species richness as a function of immigration and extinction rates. Colonization is assumed to be dependent on distance of an area from a species source pool, but independent of island size. Extinction is assumed to be inversely proportional to area.

Genetic Drift: Random fluctuation in allele frequency over time without any influence by natural selection.

GIS (Geographical Information System): "A constellation of (computer) hardware and software that integrates computer graphics with a relational database for the purpose of managing (storing, retrieving, analyzing, overlaying, displaying, printing) data about geographic locations" (Garson and Biggs, 1992).

Habitat Corridors: Linear areas of habitat linking two or more natural areas. Noss (1991a, 1997) describes four types of corridors based on scale: fencerow, landscape mosaic, regional, and continental.

Habitat Fragmentation: The process whereby "a large expanse of habitat is transformed into a number of smaller patches of smaller total area, isolated from each other by a matrix of habitats unlike the original" (Wilcove *et al.*, 1986, pg. 237).

Insular Ecology: A field of ecology which emphasizes the study of habitat fragments, fragmented habitat, and/or patchy habitats.

Integrated Resource Management: The co-ordinated, strategic planning and management of land, water, and wildlife resources within a region, involving co-operative action between public agencies, community organizations, the private sector and individuals (Burton, 1988).

Mesic: Moderately moist

Metapopulation: A collection of distinct populations loosely connected through the movement of individuals.

Minimum Habitat Area: The smallest amount of habitat required to sustain a minimum viable population of a given species.

Minimum Dynamic Area: Defined by Pickett and Thompson (1978) as "the smallest area with a natural disturbance regime, which maintains internal recolonization sources, and hence minimizes extinction" (pg. 34).

Population Viability Analysis (PVA): A risk assessment process used in assessing the probability of a population's persistence over a stated length of time (expressed as the number of individuals required to ensure a certain probability of persistence over a given length of time).

Protected Area: "An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means" (IUCN, 1994).

Recruitment: The proportion of young entering the adult population

Richness: The total number of species in a given area.

Shifting Mosaic: The conceptualization of ecosystems and spatial landscape pattern as being in a perpetual cycle of change and, when considered in broad time frames, in a nonequilibrium state.

Species-Area Relationship: Commonly expressed as a function of $S = cA^z$, where S is the number of species of a given taxon and A is the area of a given location. The result is the generalization that an order of magnitude increase in area results in a doubling of the number of species.

Umbrella Species: A target species used in protected area design. By designing a protected area on the minimum habitat area requirements of an ecosystem's most space-demanding species, it is probable that minimum habitat areas for, and thus viable populations of, all other species will also be included.

Viable Population: A population which "maintains its vigour and its potential for evolutionary adaptation" (Soule, 1987). Viable populations are large enough and diverse enough to withstand random pressures such as demographic, genetic, environmental, and catastrophic stochasticity.

APPENDIX B

PROTECTED AREA DESCRIPTIONS

I. KLUANE NATIONAL PARK AND RESERVE

Kluane National Park and Reserve is located in the extreme southwest corner of the Yukon Territory. Its western and southern boundaries follow territorial borders while its north and east boundaries skirt the edge of the St. Elias Mountains and the Haines and Alaska Highways. Icefields dominate over half of the park but give way to vegetated mountain slopes and forested valleys as one travels outward from this core area. As a result of this pattern, the peripheral zone of Kluane is often referred to as the *green belt*.

Kluane was originally set aside for National Park status in 1942 following construction of the Alaska Highway. However, mining interests effectively blocked creation of a national park until 1972, and official proclamation of the park did not come until 1976 (Theberge, 1978; McNamee, 1994). While the area was designated a game sanctuary in the years between 1942 and 1972, this status offered little protection. Minimal surveillance and enforcement allowed big game hunting to occur throughout the area until formal establishment of the National Park (Parks Canada, 1990). Peripheral areas of the game sanctuary were excluded from the final boundaries of Kluane National Park when established in 1976, despite efforts by individuals and conservation groups to incorporate these lands, or portions thereof (see section 4.3.2) (Theberge, 1978). The specific purpose and primary management objective of Kluane National Park and Reserve, as well as all other protected areas discussed in this chapter, are presented in Table 4.1.

A large portion of Kluane National Park remains under reserve status - a designation granted to an area where native land claims have yet to be settled. In 1994 the Champagne-Aishihik First Nation settled their land claim in the southwestern portion of the Yukon and a portion of Kluane was released from reserve status (Seale, 1996). The Kluane First Nation have just completed negotiations on their respective land claim, but have yet to ratify the agreement within the band. Until that time, the remainder of Kluane officially remains in reserve status.

The Canadian National Parks Act recognizes the right of First Nations to undertake subsistence harvest in National Parks. As such, local first nations have the legal right to hunt, trap, and fish within Kluane National Park. With the exception of a special "no-harvest zone" negotiated during their land claim agreement, the Champagne-Aishihik have subsistence rights in their traditional territories located within the park and the Kluane First Nations have subsistence rights in areas which remain a national park reserve. Table 4.2 provides a breakdown of this subsistence use as well as consumptive use in all other parks and protected areas discussed here.

Outside of this traditional resource use by first nation peoples, land use in the park is limited primarily to recreational activities such as hiking, backpacking, mountaineering, and fishing. Parks Canada estimates the number of annual visitors to Kluane to number around 50,000 (Parks Canada, 1990). The majority of this visitation occurs as stops to the Park's visitor reception centre in Haines Junction and the Sheep Mountain Interpretive Centre, or as day use along the Alaska Highway corridor. Registered backcountry use is less than 1000 persons per year and overnight stays at the park's Kathleen Lake campground are roughly the same. While Kluane has a reputation for being Canada's premier mountaineering location, fewer than 100 people register annually for expeditions. In short, the periphery of the park's green belt receives virtually all visitor use. As such, pressure exists for the establishment of more day use facilities in this zone and development along the highway corridor has increased substantially since park establishment (Fay, 1992).

Land use on non-park lands adjacent to Kluane extends well beyond those activities permitted in the park. As mentioned above, tourism development and infrastructure has grown considerably in the recent past and is seen as the major area for regional economic growth. Placer mining occurs on creeks and rivers throughout the area. Commercial quartz mining is also present and is forecast to grow in the future (YTG, 1992). With the exception of the Kluane Wildlife Sanctuary, commercial outfitting, guiding, and hunting occurs throughout the region. Forestry is sporadic throughout the area, although recent spruce beetle infestations have increased the amount of logging in nearby areas.

Management efforts in Kluane in the recent past have struggled with providing a balance between promoting and facilitating visitor use of the park while protecting its biological diversity and ecological integrity. The Yukon Territory has heavily promoted Kluane as a tourism destination, and local residents would like to experience the economic benefits of increased visitation. Parks Canada has proposed a number of day use developments and visitor services within the park. However, small but incremental developments within and beyond park boundaries have significant potential for negative ecological impacts (Hegmann, 1995) and there is not yet agreement on what types and how much use should occur.

Additional issues facing the park include a nearby wolf kill and outbreaks of spruce beetle within the park. The wolf kill was undertaken by the Yukon Territorial Government in an attempt to halt a decline in caribou and moose numbers in the region. The kill invoked a heated controversy across the Yukon, and could continue to have both direct and indirect impacts on protected wolf populations within Kluane National Park (Barichello, 1996). Recent outbreaks of spruce bark beetle within Kluane have raised concern amongst local residents who disagree with the Parks Canada policy of allowing natural processes to occur unchecked by human interference. They see a potential for valuable timber to be lost to the infestation or a subsequent forest fire and believe that logging in the park should be permitted to prevent this from occurring (Peepre, pers. comm., 1997).

II. TATSHENSHINI-ALSEK WILDERNESS PROVINCIAL PARK

The Tatshenshini-Alsek Wilderness Provincial Park lies in the extreme northwest corner of British Columbia in an area known as the Haines Triangle. While the focal points of the park are the Alsek and Tatshenshini River valleys, the park extends well beyond these corridors and includes a substantial area of high alpine terrain and glaciers.

The Tatshenshini-Alsek is the newest of the region's protected areas. It was established following debate over a proposed open pit copper mine at Windy Craggy Mountain, located in the heart of the Haines Triangle. The Windy Craggy mine would have extracted over 30,000 tonnes of ore per day and opponents feared significant impacts to water quality, wildlife populations and the overall wilderness character of the area

(Careless, 1993; Hood, 1995). The lobby opposing the mining development grew rapidly and garnered support from numerous organizations in Canada and beyond (Hood, 1995). Finally, in the summer of 1993, the entire area was designated a provincial park by Order-in-Council effectively eliminating any mining development from occurring. The area was upgraded to full legislated status in 1995.

Because of its recent establishment, BC Parks is just now undergoing the process of developing a management plan for the Tatshenshini-Alsek (Brown, pers. comm., 1997). Yet some specific land use restrictions are already in place. As a Class 'A' Provincial Park, all commercial resources exploitation is prohibited and any activities deemed incompatible with wilderness preservation are also prohibited (WCMC, 1997). Apart from the Haines Highway corridor which occupies less than 5% of the area, the entire park is zoned for wilderness preservation (WCMC, 1997).

As in Canadian national parks, aboriginal people have a legal right to use provincial parks in British Columbia for traditional sustenance activities. This includes hunting, fishing, and trapping which, in the Haines Triangle area, is carried out by the Champagne-Aishihik First Nation. Beyond these traditional activities, use of the park is focussed heavily on rafting along the Tatshenshini and Alsek Rivers. Approximately 1,000 people utilize the park each year for this purpose. Additional activities include remote backcountry use such as backpacking and mountaineering. A limited amount of sport hunting is permitted (UNESCO, 1998).

Management of the Tatshenshini-Alsek focuses on use of the river corridors in the park and ensuring that environmental impacts from river use are minimized. Use of the area has increased over 200% in the past few years, compounding such management issues (WCMC, 1997). Furthermore, pressure still exists from portions of the Canadian mining industry to allow mining within the park, although the Ministry of Energy, Mines and Petroleum Resources is attempting to negotiate compensation for the 171 mineral claims which predate park designation.

III. WRANGELL-ST. ELIAS NATIONAL PARK AND PRESERVE

Wrangell-St. Elias National Park and Preserve is the largest unit of the United States' national park system. The park extends from the Alaska-Yukon border west to the Copper River, and south from the Mentasta and Nutzotin mountains to the Gulf of Alaska. Wrangell-St. Elias is partially bisected by the wide Chitina river valley; to the north of the valley lie the Wrangell Mountains and to the south lie the Chugach Mountains. At the head of the valley lie the St. Elias Mountains.

The potential for protecting the Alaskan portions of the Wrangell and St. Elias Mountains had been discussed since the 1930s (Lappen, 1984). However, comprehensive deliberations did not occur until passage of the Alaska Native Claims Settlement Act (ANCSA) in 1971. While the purpose of ANCSA was to settle aboriginal land claims, it also authorized withdrawal of 32 million hectares of public lands for protected area consideration. At least eight land designation proposals for the Wrangell and St. Elias mountains followed, including a combination of national forest, national park, national preserve, and state resource land status (Wright, 1984). The process of federal land designation in Alaska culminated in 1980 with the passage of the Alaska National Interest Lands Conservation Act (ANILCA). ANILCA established ten new parks and preserves in Alaska totalling 153,000 km^2 - including Wrangell-St. Elias Wright, 1985; Wright, 1996b).

The national preserve designation, which permits sport hunting, was a product of the statewide planning process that occurred between passage of ANCSA and ANILCA. Given the level of sport hunting that occurs in Alaska and the fact that US national parks are closed to sport hunting, a land designation compromise was forced. As Wright (1996b) states, "it was necessary politically to allow sport hunting to occur on some of the lands under study, or otherwise be forced to settle for a much smaller parks, with diminished ecological integrity". Nearly 20,000 km^2 of Wrangell-St. Elias is under national preserve status. The final preserve boundaries were established *via* a process which utilized harvest data for Dall sheep, the area's most sought after big-game species (see Wright, 1984 and 1985). However, unlike other national parks in Alaska, which have preserve lands located adjacent to park lands, the two designations intermingle in

Wrangell-St. Elias.

The US National Park Act specifies that the purposes of a national park are to "conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (NPS, 1986). ANILCA specifies additional purposes for National Parks located in Alaska. Those for Wrangell St. Elias are presented in Table 4.1 along with specific management objectives identified in the Park and Preserve's General Management Plan.

Given the park's legal commitment to allow for continuation of subsistence lifestyles, traditional resource use by local residents is permitted throughout the park and preserve. To be considered a local resident, and therefore be entitled to subsistence use of national park lands, an individual must live in an area that has been identified by park management as a local community. Methods by which subsistence use is carried out is also regulated (FSB, 1997) and a recent study by Haynes and Walker (1995) has assisted in identifying traditional access routes and methods of subsistence use within the park and preserve.

Recreational use of the park and preserve includes activities such as landscape sightseeing from road corridors, historical sightseeing in and around the historical mining communities of Kennicott and McCarthy, "flightseeing", fishing, hiking, backpacking, all-terrain-vehicle (ATV) use, sport hunting (on preserve lands), and mountaineering. Wrangell-St. Elias receives approximately 25,000 visitors per year. As with Kluane, most of this visitation occurs along or near areas accessible by road. This includes most of the western border of the park and the McCarthy Road corridor which extends into the park along the Chitina river.

Some preserve lands and much of the National Park are legislated as Wilderness under the Wilderness Act of 1964, and land use and activities on these lands must adhere to strict regulations. Unlike the other three core St. Elias Mountain Parks, Wrangell-St. Elias contains a significant amount of private landholdings within its boundaries. Approximately 10% of the park's area is non-federal land, including the town of McCarthy located in the heart of Wrangell-St. Elias. Land use on these inholdings is subject to a complex mix of regulations. This land ownership and land designation complexity significantly complicates management of Wrangell-St. Elias. Park users must be aware of what regulations apply to what lands and whether the activities they are carrying out are in accordance of such regulations. Such complexity irritated local residents when the park was first established as they had used the land freely until that point. Animosity between some residents and park staff still exists today.

As with Kluane and the Tatshenshini-Alsek, managers of Wrangell-St. Elias struggle to find a balance between visitor use and park preservation. Local residents and the State of Alaska see a great deal of potential for the park to act as a focus for tourism and economic development in the region. But the National Park Service must ensure that the reasons for the park's establishment are not compromised. Additional management and land use issues are discussed further in section 4.5.

IV. GLACIER BAY NATIONAL PARK AND PRESERVE

Glacier Bay National Park and Preserve occupies a peninsula that constitutes the southernmost portions of the St. Elias Mountains. The park derives its name from a saltwater bay that penetrates the southern end of the peninsula northward for nearly 100 km and acts as the heart of the present park. The bay was actually hidden under a vast ice sheet when the first Europeans explored the area in the late 18th century. When American naturalist John Muir explored the area in 1879, he found that the glaciers had retreated approximately 77 km up bay. The ice sheet is still receding and the bay now contains 17 tidal glaciers.

The combination of receding ice and ecological succession on recently deglaciated land has made Glacier Bay an international Mecca for scientific study, one of the main reasons for the park's establishment (see Table 4.1). The Bay and surrounding lands were designated a National Monument in 1925. The monument was then expanded in 1939, and became a National Park under ANILCA in 1980. As noted by Catton (1995), the legislated mandate for scientific research at Glacier Bay makes it unique amongst US national parks and plays a significant role in how the park is utilized and managed today.

Of the more than 250,000 people who visited Glacier Bay National Park in 1995, roughly 200,000 came aboard cruise ships. As such, sightseeing from the water is the most popular park activity, and park staff must accompany any large boats entering the bay. Most of the 50,000 remaining visitors also spend the majority of their time on or near the water. Glacier Bay is well known for recreational activities such as kayaking and backcountry use of the park is focussed heavily on coastal areas. Moreover, all frontcountry facilities are located on or near the water. As such, most issues and concerns in the management of Glacier Bay National Park are marine in nature, and significantly different than in the other three parks.

A small portion of Glacier Bay (234 km^2) is protected as a national preserve where sport and subsistence hunting is permitted. And while subsistence hunting is not permitted within Glacier Bay National Park, commercial fishing continues to occur in Glacier Bay itself - despite the fact that commercial fishing was ruled illegal in all National Parks in 1984. The National Park Service has proposed regulations to phase out commercial fishing in Glacier Bay, but given the long history of this activity, they are being met with strong resistance (Moss, pers. comm., 1997).

Boat use on Glacier Bay is also a major issue. Declines in the number of marine mammals using the bay in the 1970s, notably Humpback Whales, appeared to be related to heavy boat traffic, and led to the regulation of boat use on the bay. Such regulation has become "the cornerstone of resource management in Glacier Bay National Park" (NPS, 1997), and a far-sighted vessel management plan was implemented in 1995 to limit the number of commercial and private vessels on the bay at any one time.

V. TETLIN NATIONAL WILDLIFE REFUGE

Tetlin National Wildlife Refuge was established under ANILCA in 1980. Roughly triangular in shape, the northern portion of the refuge occupies an area of boreal lowlands dotted with small lakes and wetlands. The more southern portions flank the Mentasta and Nutzotin mountains. Two major rivers, the Nabesna and Chisana, run in a south-north direction through the refuge and converge to form the Tanana river at the park's northern boundary.

The mission of the National Wildlife Refuge System is "to provide, preserve, restore, and manage a national network of lands and waters sufficient in size, diversity, and location to meet society's needs for areas where the widest possible spectrum of benefits associated with wildlife and wildlands is enhanced and made available" (FWS, 1987). The specific purposes of Tetlin are: 1) To conserve fish and wildlife populations and habitats in their natural diversity; 2) To fulfill the international treaty obligations of the United States with respect to fish and wildlife and their habitats; 3) To provide the opportunity for continued subsistence uses by local residents consistent with the above purposes; 4) To ensure water quality and quantity is maintained to the maximum practical extent; and, 5) To provide in a manner consistent with 1 and 2 (above), opportunities for interpretation and environmental education.

The National Wildlife Refuge System Administration Act of 1966 established compatibility standards requiring that all public uses permitted on refuge lands be compatible with the primary purposes for which the area was established (Young *et al.*, 1990). Hunting is permitted within the refuge and mining in a legitimately claimed area is also permitted. Commercial logging is not normally allowed unless undertaken in conjunction with management purposes. Habitat management for specific species groups - particularly waterfowl and ungulates - is practised extensively throughout the Refuge, primarily through prescribed burns to encourage new growth. The refuge employs its own full time Fire Control Officer and associated crew.

Tetlin is one of only two national wildlife refuges accessible by road in Alaska. This accessibility was the rationale for including interpretation and environmental education as one of the Refuge's objectives. A large portion of its border abuts the Alaska Highway and the refuge estimates annual visitation at approximately 160,000 per year (FWS, 1992). Most of this visitation occurs along the highway corridor and there is relatively little use of the refuge's interior, even for hunting (Doyle, pers. comm., 1997). Roughly 25%, of Tetlin NWR is privately owned and subject to state regulations.

VI. KLUANE WILDLIFE SANCTUARY

The Kluane Wildlife Sanctuary (formerly known as the Kluane Game Sanctuary) lies adjacent to Kluane National Park in three separate areas totalling approximately 6,368 km^2. The northern portion is the largest of the three areas. The remaining two areas are located south of Kluane Lake and occupy those lands between the national park and the Haines and Alaska Highways.

The Kluane Wildlife Sanctuary was originally established in 1943. Boundary adjustments occurred frequently in the following years until 1976 when a large portion of the sanctuary was officially designated as Kluane National Park. While it was the original intent to establish the entire area as a national park, it is generally recognized that the decision to maintain the three wildlife sanctuary areas was a concession granted to mining interests when the final park boundaries were drawn (Theberge, 1978; McNamee, 1994). Attempts by the National and Provincial Parks Association of Canada to have portions of the sanctuary added to Kluane National Park were unsuccessful, as were attempts by the Yukon Chamber of Mines to have portions of Kluane National Park deleted and added to the sanctuary (see Theberge, 1974; Theberge and Oosenberg, 1975; Carruthers, 1976). Designation of the western portion of the northern sanctuary as a Territorial Park will be a likely outcome of the land claim negotiations occurring between the Yukon Government and the Kluane and White River First Nations (Peepre, pers. comm., 1997; West, pers. comm., 1998). This park is likely to be centred on the Klutlan Glacier area, although the exact final boundaries have yet to be established.

The Kluane Wildlife Sanctuary is administered by both the federal and territorial governments. Like other wildlife sanctuaries in the Yukon, the land and timber resources are federally owned and administered, yet wildlife resources are managed by the Yukon Department of Renewable Resources. The only restriction on resource use within the sanctuary is a territorially assigned prohibition of "hunting, trapping, killing, shooting at, wounding, injuring, or molesting any game" (Theberge, 1978). Apart from this, the area is open to any activity that would permissibly occur on all other Territorial lands. There is no management plan for the Sanctuary and no staffing.

VII. CHILKAT BALD EAGLE PRESERVE

At 200 km^2, The Chilkat River State Critical Habitat Area, commonly known as the Chilkat Bald Eagle Preserve, is the smallest of the protected areas in the St. Elias Region. The preserve is located along a stretch of the Chilkat River near the head of the Lyn Canal. It was established in 1982 to protect habitat for the world's largest concentration of Bald Eagles *(Haliaeetus leucocephalus)*. The warm water of the Chilkat River facilitates salmon runs late in the year and thousands of eagles from across southeast and south-central Alaska congregate here in late fall and early winter to feed on spawned out salmon. Despite its size and the fact that the preserve lies at the fringe of the St. Elias region, it serves an important ecological role at both the local and regional scale.

The Chilkat Preserve is an Alaskan State Critical Habitat Area, one of three legal designations used by the state of Alaska for the preservation of significant wildlife areas. Management of these areas is the responsibility of the Alaska Department of Fish and Game (ADF&G). The preserve is managed for the purposes of protecting bald eagle populations and their habitats, protecting salmon spawning and rearing areas, protecting riparian ecosystems, protecting populations of other bird and mammal species, and providing opportunities for scientific study and research (ADNR, 1985). Land use is managed under these directives, and the preserve is divided into five management units for which detailed land use guidelines have been developed.

VIII. TONGASS AND CHUGACH NATIONAL FORESTS

Two national forests - Tongass and Chugach - occupy portions of the greater St. Elias Region. Each are managed by the US National Forest Service, and share its overall goal of “protecting natural resources, securing favourable water flows, and providing a sustainable flow of commodities for current and future generations” via the canons of multiple use and sustained yield (Tuchmann *et al.*, 1996, pg. 13). National forest planning in the US is widely viewed as “one of the most complex and difficult planning efforts in the nation” (Tuchmann *et al.*, 1996, pg. 16). Both Tongass and Chugach National Forests have extensive land management plans that are revised every 10 to 15 years. Each forest is a patchwork of land designations where permitted land use ranges from intensive logging and resource extraction to legislated Wilderness areas where all resource extraction and motorized access is prohibited.

Tongass National Forest was established in 1902 as the Alexander Archipelago Forest Reserve. Renamed in 1907, it has undergone numerous additions and boundary changes since that time (Sisk, 1989). At 70,606 km^2, it covers nearly the entirety of southeast Alaska and is the largest National Forest in the United States. However, only a portion of Tongass can be considered part of the St. Elias region. The Yakutat Area, the stretch of Alaska between Yakutat Bay and Dry Bay on the Gulf of Alaska and areas along the Lyn Canal are most relevant to this study. These portions of the Forest include two legislated Wilderness areas - the Russell Fiord Wilderness (1,411 km^2) and the Endicott River Wilderness (400 km^2). Three additional wilderness areas - Kootznoowoo (Admiralty Island) Wilderness (3,999 km^2), West Chichigoff-Yakobi Wilderness (1075 km^2), and Pleasant-Lemusurier-Inian Islands Wilderness (94 km^2) - lie immediately south of the study area (USFS, 1997).

Chugach National Forest was established in 1907 and is the second largest national forest in the United States at 27,959 km^2. Like Tongass, it extends well beyond the greater St. Elias region. For management purposes the Chugach is divided into 3 geographical areas and it is the Copper River Management Area (7,770 km^2) that is most relevant to this study. Unlike Tongass however, the Chugach contains no wilderness areas. However, special preservation areas do exist within Chugach, and in the Copper River management area this includes the Copper River Delta (USFS, 1984). This area has been designated as a State Critical Habitat area for the purposes of protecting and preserving intertidal areas, upland marshes, river floodplains, and other areas heavily utilized by migrating shorebirds and staging waterfowl. The designation applies to all private lands not encompassed by the National Forest.

APPENDIX C

GIS METADATA

SOURCES

Maps were obtained in both digital and paper format. Those in digital format were converted to MapInfo and data structure was adjusted as necessary. Paper maps were digitized directly into MapInfo. Digitizing accuracy was assessed by using a quadrat sampling methodology whereby several areas of the digitized image were intensively checked against the original map. Corrections were made whenever significant error was encountered. Digital image resolution was assessed using the *minimum mapping unit* (MMU) technique described by Goodchild and Quattrochi (1997). Resolution obviously varied from map to map depending on the source scale. However, as a standard measure, the MMU did not exceed 500 metres (i.e. 25 ha) for maps generated at a scale of 1:250,000. In most cases, quantitative and qualitative data was added from additional sources to both the preexisting digital coverages and digitized coverages.

PROJECTION AND COORDINATE SYSTEM

The map sources, both paper and digital formats, utilized a wide variety of projections and coordinate systems. The projection and coordinate system chosen for the regional database is the Albers Equal-Area Standard Alaskan Projection which is commonly used in state-wide coverages of Alaska. It was also chosen because of its ability to display western Yukon and northwestern British Columbia without distortion relative to Alaskan portions of the same map. The coordinate system is as follows:

Projection: Albers Equal Area
Units: Metres
Central Meridian: -154.00
Datum: NAD 1927
1st Standard Parallel: 55.00
2nd Standard Parallel: 65.00
False Northing: 0
False Easting: 0

The projections chosen for storage of the 1:250,000 quadrangle map sheets was the standard UTM grid with each map sheet stored in its respective UTM zone.

DIRECTORY STRUCTURE

The GIS database has been stored in several directories, each containing similar types of data and map layers. Primary directories are based on the spatial extent of the data (i.e. region-wide coverages, state/provincial/territorial coverages, UTM quadrangle coverages). The following provides the breakdown of the main directories and their subdirectories.

- e_141 (UTM base map coverages from east of -141°)
- w_141 (UTM base map coverages from west of -141°)
- quads (UTM base map coverages)
- region (region-wide thematic coverages)
  - admin
  - basemaps
  - relief
  - human
  - biologic
  - physical
  - workspace
- statemaps (state/territorial/provincial thematic coverages)
  - alaska
  - bc
  - yukon

PARKS AND PROTECTED AREAS - BOUNDARIES
(st_elias/region/human/parks1.*, parks2.*)

Sources
ADFG (Alaska Department of Fish and Game). 1985. Chilkat Bald Eagle Preserve Management Plan. ADFG, Habitat Branch, Juneau, AK.

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping Branch, USGS, Washington, DC.

Data Structure (5 Fields)
i. *Name* refers to the full name of the protected area.
ii. *Class* refers to the class of protected area (e.g. national park, provincial park, etc.)
iii. *Authority* refers to the agency responsible for management of the area.
iv. *Level* refers to the level of government to which the authority belongs.
v. *IUCN* refers to the protected area designation given to the area by the IUCN (ranked 1-6).

Methods and Miscellaneous Notes
Outer boundaries (parks1.*) and internal boundaries (parks2.*) were digitized from the relevant 1:250,000 scale map sheets. Park management plans were consulted for boundary verification and to delineate special management areas not noted on the source maps. Polygon areas in square kilometres were compared with officially documented areas for accuracy and only fractional differences were encountered. Boundaries for the Chilkat Bald Eagle Preserve were digitized from maps contained in the area's management plan.

PARKS AND PROTECTED AREAS - WILDERNESS
(st_elias/region/human/parks3.*)

Sources

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

Parks Canada. 1990. Kluane National Park Reserve Management Plan. Environment Canada, Parks Canada - Prairie and Northern Region, Winnipeg, MA.

USFWS (US Fish and Wildlife Service). 1987. Final Comprehensive Conservation Plan, Environmental Impact Statement, Wilderness Review: Tetlin National Wildlife Refuge. USDI Fish and Wildlife Service, Anchorage, AK.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping Branch, USGS, Washington, DC.

USNPS (US National Park Service). 1984. General Management Plan, Land Protection Plan, Wilderness Suitability Review: Wrangell St. Elias National Park and Preserve. USDI National Park Service, Anchorage, AK.

USNPS (US National Park Service). 1984. General Management Plan: Glacier Bay National Park and Preserve. USDI National Park Service, Anchorage, AK.

Data Structure (2 Fields)

i. *Name* refers to the full name of the protected area.
ii. *Authority* refers to the agency responsible for management of the wilderness area.

Methods and Miscellaneous Notes

Federally designated wilderness boundaries in Alaska were digitized from the relevant 1:250,000 scale topographic map sheets. Management plans were consulted for boundary verification and updates. There is no direct equivalent for Canadian areas. Instead, the Kluane National Park Management Plan and BC Parks staff were consulted to assist in delineating those areas in Kluane National Park and Tatshenshini-Alsek Provincial Park where motorized access or commercial resource extraction is permitted. These areas were considered non-wilderness and were deleted from the outer boundary polygons. Polygon areas in square kilometres were compared with officially documented areas for accuracy; only fractional differences were encountered.

TOWNS AND ROADS

(st_elias/region/human/towns.*, roads.*)

Sources

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping Branch, USGS, Washington, DC.

Data Structure (2 Fields, 2 Tables)

i. *Name* of the town or road.

ii. *Class* represents the size of the town or road relative to others in the region on a scale of one to three.

Methods and Miscellaneous Notes

Towns were digitized as points from the 1:250,000 topographic base maps published by USGS and NRCan. Roads were digitized as polylines from the 1:250,000 topographic base maps published by USGS and NRCan. Trails, all-terrain roads, and other such routes are not included on this datalayer.

LAND OWNERSHIP AND MANAGEMENT JURISDICTION
(st_elias/region//admin/federal.*, state.*, native.*, selected.*)

Sources

Geisleman, J., J. Dunlap, P. Hooge, and D. Albert. 1997. Glacier Bay Ecosystem GIS CD-ROM Set. US Geological Survey and Interrain Pacific, Anchorage and Juneau, AK.

Oakley, K. *et al.* 1996. Prince William Sound/Copper River Ecosystem GIS CD-ROM. US Geological Survey, Anchorage, AK, and Pacific GIS, Portland, OR.

YDRR (Yukon Department of Renewable Resources). 1997. Yukon First Nation Traditional Territories. Digital map at 1:250,000 scale. Yukon Department of Renewable Resources, GIS Unit, Whitehorse, YT.

YDRR (Yukon Department of Renewable Resources). 1997. Yukon First Nation Settlement Lands. Digital map at 1:250,000 scale. Yukon Department of Renewable Resources, GIS Unit, Whitehorse, YT.

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping Branch, USGS, Washington, DC.

Data Structure (4 Fields, 4 Files)

i. *Level* of ownership (Federal, State, Territory, Province, Municipal, Native, Private)
ii. *Department* which holds management jurisdiction (e.g. USDI, USDA, DIAND, BCMELP, Yukon First Nations, Alaska Native Corporation, etc.)
iii. *Agency* which administers land management (e.g. NPS, Parks Canada, USFS, BLM, etc.
iv. *Status* (patented or conveyed)

Methods and Miscellaneous Notes

The Alaskan Land Status file set maintained by the Department of Natural Resources was obtained from the Glacier Bay GIS CD-ROM set. This set of files denotes general land ownership across the entire state. The files were converted from Arc format to MapInfo by way of intermediate stage ArcView Shape files. BLM land in Alaska seemed to be incomplete, and after cross referencing with a similar data set contained on the Prince William Sound data set, the decision was made to combine the two files. Protected area boundaries were based on those digitized from 1:250,000 topographic basemaps.

First Nations land status in the Yukon was based on the digital maps provided by Yukon Renewable Resources. Ongoing land claim negotiations with the Kluane and White River First Nations should be finalized sometime before 2000. As such, lands owned by these two First Nations are not included in this data set. Protected area boundaries are based on those digitized from 1:250,000 topographic basemaps.

Lands which are currently selected for conveyance in Alaska, and traditional territories of Yukon First Nations are contained in the "selected.*" file set so they can be overlayed on the above data sets.

Final scale of these data layers is highly variable due to the numerous data sources, with a maximum of 1:250,000 and minimum of 1:1,000,000.

The following quote, which refers to Alaska, is taken from The Glacier Bay GIS metadata suite and is equally applicable to Yukon and British Columbia:

> "The most serious limitation with any land status layer in a GIS is the dynamic nature of the land ownership changes. Alaska is still in a process of transferring lands from federal to state and Native corporation ownership and from state to private ownership under the Alaska Statehood Act, the Alaska Native Claims Settlement Act, and various state homestead and land disposal programs. With this level of change affecting large acreages, a land status layer is seldom completely up to date."

Overlapping polygons are a direct result of this complex data set. As a result, it has been stored in four separate files to allow for layering of polygons in thematic map generation.

TECTONIC TERRANES
(st_elias/region/physical/terranes.*)

Sources

Jones, D.L., N.J. Silberling, P.J. Coney, and G. Plafker. 1987. Lithotectonic Terranes of Alaska (west of the 141st meridian). Paper map at 1:2,500,000. MF-1874-A. US Geological Survey, Anchorage, AK.

Monger, J.W.H. and H.C. Berg. 1987. Lithotectonic Terranes of Western Canada and Southeastern Alaska. Paper map at 1:2,500,000. MF-1874-B. US Geological Survey, Anchorage, AK.

Silberling, N.J., D.L. Jones, J.W.H. Monger, and P.J. Coney. 1992. Lithotectonic Terrane Map of the North American Cordillera. Paper map at 1:5,000,000. US Geological Survey, Denver, CO.

Data Structure (3 Fields)

i. *abrv* (name abbreviation)
ii. *name* (full name)
iii. *age* (geologic era of formation)

Methods and Miscellaneous Notes

The two 1:2,500,000 map sources were digitized into MapInfo. Required edge-matching was minimal as the original authors had collaborated during map production and a common terrane nomenclature and classification was utilized. Information on the various terranes for the map key was supplemented with information from Silberling *et al.*, 1992.

The two primary maps utilized here were created as part of a joint USGS-GSC project to map lithotectonic terranes for all of western North America. The final product to illustrate the entire cordillera was the map created by Silberling *et al.* (1992). However, that map was generated at a much smaller scale of 1:5,000,000 and generalized and omitted a number of features that had been identified at 1:2,000,000. Therefore the two larger scale maps were utilized for this project.

EARTHQUAKES
(st_elias/region/physical/quakes.*)

Sources
USGS (United States Geological Survey). 1998. National Earthquake Information Center Database. Data accessed at http://www.neic.cr.usgs.gov/neis/epic/epic.html.

UAF (University of Alaska at Fairbanks). 1998. Alaska Earthquake Information Center Database. Data accessed at http://aeic.alaska.edu/seis/html_docs/db2catalog.html.

NRCan (Natural Resources Canada). 1998. National Earthquake Database. Data accessed at http://seismo.nrcan.gc.ca/database/eq_db_e.html.

Data Structure (9 Fields)
i. *Latitude* of the epicentre
ii. *Longitude* of the epicentre
iii. *Magnitude* of the earthquake
iv. *Depth* of the epicentre, estimated in kilometres
v. *Year* of the event
vi. *Month* of the event
vii. *Day* of the event
viii. *Time* of the event
ix. *Source* of the data

Methods and Miscellaneous Notes
Earthquake data was obtained from the USGS National Earthquake Database, the Alaska Earthquake Information Center, and the NRCan Earthquake Database. Data was obtained on all earthquakes greater than 4.0 magnitude that have been recorded since 1973. (Records of events prior to the 1970s are sporadic and biased toward high magnitude events.) This included date and time of the event, magnitude, location, and epicenter location and depth. A spreadsheet was imported into MapInfo and data was mapped as points based on lat-long coordinates.

GEOLOGIC FAULTS
(st_elias/region/physical/faults.*)

Sources

Beikman, H.M. 1980. *Geologic Map of Alaska*. Paper map at 1:2,500,000. US Geological Survey, Anchorage, AK.

Geological Survey of Canada (GSC). 1981. *Tectonic Assemblage Map of the Canadian Cordillera and Adjacent Parts of the United States of America*. Paper map at 1:2,500,000. Geological Survey of Canada, Surveys and Mapping Branch, Ottawa, ON.

Data Structure (3 Fields)

i. *Name* of the fault is given where one has been assigned
ii. *Age* of the fault is listed as either pre or post neogene where known
iii. *Type* of fault, where known, is given as either a thrust or strike-slip fault

Methods and Miscellaneous Notes

The location of major faults was obtained from a variety of literature sources and maps. Those faults coinciding with tectonic terrane boundaries were matched with boundaries logged in the file *terranes.**. Additional faults were digitized from Beikman (1980) and GSC (1981).

GEOTHERMAL AND VOLCANIC FEATURES
(st_elias/region/physical/thermal.*)

Sources

Beikman, H.M. 1980. *Geologic Map of Alaska*. Paper map at 1:2,500,000. US Geological Survey, Anchorage, AK.

Geological Survey of Canada (GSC). 1981. *Tectonic Assemblage Map of the Canadian Cordillera and Adjacent Parts of the United States of America*. Paper map at 1:2,500,000. Geological Survey of Canada, Surveys and Mapping Branch, Ottawa, ON.

Richter, D.A., D.S. Rosenkrans, and M.J. Stiegerwald. 1995. *Guide to the Volcanoes of the Western Wrangell Mountains, Alaska*. Bulletin 2072. US Geological Survey, Washington, D.C.

Richter, D.H., J.G. Smith, M.A. Lanphere, G.B. Dalrymple, B.L. Reed, and N. Shew. 1990. *Age and Progression of Volcanism, Wrangell Volcanic Field, Alaska*. Bulletin of Volcanology, 53: 29-44.

Data Structure (3 Fields)

i. *Name* of the feature (where named)
ii. *Type* of feature (i.e. volcano, hotspring, mud-volcano)
iii. *Status* of the feature (i.e. active, dormant, extinct)

Methods and Miscellaneous Notes

A list of volcanos and geothermal features to be mapped was developed from review of a variety of literature sources. Point data was then added to the dataset using latitude and longitude coordinates.

ELEVATION CONTOURS
(st_elias/region/physical/relief.*)

Sources
ESRI (Environmental Systems Reseach Institute). 1996. Digital Chart of the World - Hypsography. Third Edition. Digital Maps at 1:1,000,000. ESRI, Portland, OR.

Data Structure (3 Tables, 1 Field each)
i. *Elevation* in feet above sea level (contour interval of 1000 feet)

Methods and Miscellaneous Notes
Digital hypsography files from the Digital Chart of the World were obtained from the Penn State University Digital Map Library (http://www.maproom.psu.edu/dcw) and converted to MapInfo format using ArcLink. Three files were obtained: one each for Alaska, Yukon, and British Columbia. Required edge-matching was minimal due to the single data source. However, most contour lines on the original files were missing elevation data or existing elevation data was incorrect. By necessity, this process was undertaken manually and polylines were converted to polygons for this process.

LAKES AND RIVERS

(st_elias/region/physical/lakes.*, rivers.*)

Sources

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping Branch, USGS, Washington, DC.

Data Structure (2 Fields, 2 Tables)

i. *Name* of the lake or river is given.

ii. *Area* or *Length* is given in kilometres or square kilometres.

Methods and Miscellaneous Notes

Lakes and rivers were digitized from the 1:250,000 topographic base maps published by USGS and NRCan. Rivers appearring as polygons on the map sheet (i.e. double edged streams) were classified as lakes so as to retain polygons and polylines in separate layers.

Not all lakes and rivers have a name attached to them. Reference to the original map sheet may be necessary for this information.

COASTLINE AND OCEAN

(st_elias/region/basemaps/coast.*, ocean.*)

Sources

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping Branch, USGS, Washington, DC.

Methods and Miscellaneous Notes

Coastline was digitized from the 1:250,000 topographic base maps published by USGS and NRCan. Coastline was retained as polylines in the coast.* file set. Coasline was converted to polygons for the ocean.* file set.

FOREST COVER AND WETLANDS
(st_elias/region/habitat/forest.*, wetlands.*)

Sources
EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping Branch, USGS, Washington, DC.

Data Structure (1 Field, 2 Tables)
i. *Area* of the forest or wetland polygon is given in square kilometres.

Methods and Miscellaneous Notes
Polygons were digitized from the 1:250,000 topographic base maps published by USGS and NRCan.

PERMANENT SNOW AND ICE
(st_elias/region/physical/glaciers.*)

Sources
EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping Branch, USGS, Washington, DC.

Data Structure (1 Field)
i. *Area* is given in square kilometres.

Methods and Miscellaneous Notes
Permanent snow and ice, including icefields and glaciers, was digitized from the 1:250,000 topographic base maps published by USGS and NRCan. Some minor adjustments were necessary to match map sheets together. Adjoining polygons from separate map sheets were combined when it was readily evident that the resulting polygon would not exceed MapInfo’s maximum allowable number of single object nodes.

Glacier names are not included as a field in this layer because of the continuous extent of snow and ice in the region. The permiter of a mapped ice mass was followed during digitizing and, therefore, a single polygon may actually constitute several glaciers.

PHYSIOGRAPHIC DIVISIONS

(st_elias/region/physical/physiog.*)

Sources

Bostock, H.S. 1948. Physiography of the Canadian Cordillera with Special Reference to the Area North of the Fifty-fifth Parallel. GSC Memoir 247, accompanied by Map 922a at 1:2,534,000. Canadian Department of Mines and Resources, Mines and Geology Branch, Ottawa, ON.

Mathews, W.H. 1986. Physiography of the Canadian Cordillera. Map 1701a, 1:5,000,000. Geological Survey of Canada, Ottawa, ON.

Wahrhaftig, C. 1965. Physiographic Divisions of Alaska. Professional Paper 482, accompanied by map at 1:2,500,000. US Geological Survey, Washington, D.C.

Williams, H. (ed.). 1958. Landscapes of Alaska: Their Geologic Evolution. University of California Press, Berkely, CA.

Data Structure (4 Fields)

i. *Division* refers to the name of the physiographic division

ii. *Unit* refers to the hierarchical physiographic region of which the division is a part of (only where applicable)

iii. System refers to the North American physiographic system the division is a part of (Pacific Mountain System or Intermontane Plateaus)

iv. *Topography* is a description used to characterize the topographic nature of the division. Four descriptions are used (High Rugged Mountains, Moderately High Rugged Mountains, Low Rolling Mountains, Lowlands and Intermountain Valleys)

Methods and Miscellaneous Notes

Physiographic divisions were digitized from Wahrhaftig and Bostock with supplementary divisions taken from Mathews. Edge matching was complicated slightly due to the different classifications utilized by each author. Accompanying text as well as USGS and NRCAN topographic maps were consulted in these instances to make the adjustments necessary for a continuous map layer. See “Notes” below for a further discussion.

The regions delineated on the map are based on the physiographic "sections" defined by Clyde Wahrhaftig in 1965 for the state of Alaska, and the physiographic "areas" for the Canadian Cordillera defined by H.S. Bostock in 1948 and by Matthews in 1986. Bostock's classification was the first systematic division undertaken for the Cordilleran north of 49^{N} and followed closely on the heels of Fenneman and other's 1946 division of the conterminous United States. Matthews’ 1986 division of the Canadian Cordillera differs slightly from Bostock's interpretation by dividing some of the larger regions into smaller independent regions and avoiding the use of a systematic hierarchical classification. Wahrhaftig's "sections" of Alaska were preferred over William's (1958) "landscapes" of Alaska because of their finer scale of delineation and compatibility with the Canadian delineations.

Acknowledging the transboundary nature of his study, Wahrhaftig intentionally attempted to match his delineations with those of Bostock along the international border. However, the two authors utilized somewhat different hierarchical classification schemes. Each author recognized the division of the North American Cordillera into three basic "belts" or "major divisions". Thereafter, each author split these regions into very different groupings. To accommodate these differences, the scheme utilized here is similar to that used by Matthews in that it avoids a systematic hierarchy. Grouping of the individual divisions into broader provinces is undertaken not out of necessity, but only where it appears to be naturally justified. Furthermore, a hierarchical system was unwarranted given the size of the St. Elias region and the scale of delineation.

WATERSHEDS

(st_elias/region/physical/watsheds.*)

Sources

BC MELP (British Columbia Ministry of Environment, Lands, and Parks). 1997. BC Watershed Atlas. Digital Maps at 1:50,000.

USGS (United States Geological Survey). 1997. Alaska Hydrological Units. Digital Map at 1:250,000. USGS, Anchorage, AK.

Parks Canada. No Date. Drainage of Kluane National Park. Paper Map at 1:1,000,000. Parks Canada, Haines Junction, YT.

Data Structure (2 Fields)

i. *Name* of the watershed
ii. *Area* of the watershed

Methods and Miscellaneous Notes

Watershed divides in digital format were imported into MapInfo. Edge matching was difficult due to the variation in scale but was achieved by way of referencing the lakes, rivers, and elevation layers which were already completed. Yukon watershed divides were identified on paper copies of the 1:250,000 NTS map sheets and then digitized. Delineation of watershed divides in glacial areas proved difficult and the Parks Canada reference was utilized to assist in macro-delineation. Topographic variations were used for micro-delineation in these areas.

CLIMATIC DATA
(st_elias/region/physical/climate.*)

Sources

Environment Canada. 1998. Canadian Climate and Water Information and Data Site: Canadian Climate Normals, 1961-1990. Accessed via the internet at http://www.cmc.ec.gc.ca/climate/normals/eprovwmo.htm.

Gray, B. 1987. *Kluane National Park Reserve: Resource Description and Analysis*. Two Volumes. Environment Canada, Parks Canada - Prairie and Northern Region, Winnipeg, MA.

NOAA (National Oceanic and Atmospheric Administration). 1998. *Western Regional Climate Center Electronic Database*. Accessed via the internet at http://www.wrcc.sage.dri.edu/summary/climsak.html.

Wahl, H.E. , D.B. Fraser, R.C. Harvey, J.B. Maxwell. 1987. *Climate of Yukon*. Climatological Studies No. 40. Atmospheric Environment Services, Environment Canada, Ottawa, ON.

Webber, B.L. 1974. *The Climate of Kluane National Park, Yukon Territory*. Project Report No. 16. Atmospheric Environment Services, Environment Canada, Toronto, ON.

Data Structure (4 Fields)

i. *Station* represents the weather station at which the data was collected
ii. *x_MinTemp*: Mean minimum monthly temperature
iii. *x_MaxTemp:* Mean maximum monthly temperature
iv. *x_AnnTemp:* Mean annual temperature
v. *x_Precip:* Mean annual precipitation

Methods and Miscellaneous Notes

Stations were mapped based on coordinates cited by the above references. Temperature data and precipitation data were then added to each data point. US data was obtained entirely from NOAA. Data from long-established Yukon stations was data was obtained from Environment Canada. Data obtained from short term stations was compiled from Wahl *et al.*, Webber, and Gray.

DALL SHEEP RANGE
(st_elias/region/wildlife/sheep_r.*)

Sources
ADF&G (Alaska Department of Fish and Game). 1973. Alaska's Fish and Wildlife. Paper maps generated at 1:250,000 and reduced to 1:1,000,000. Alaska Department of Fish and Game, Habitat Branch, Juneau, AK.

Demarchi, D.A. and A.C. Stewart. 1974. Mountain Sheep Distribution. Paper map at 1:1,500,000. British Columbia Environment and Land Use Committee Secretariat, Victoria, BC.

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

Gray, B. 1987. Kluane National Park Resource Description and Analysis. Important Wildlife Habitat Areas 1. Paper map at 1:500,000. Parks Canada, Prairie and Northern Region, Winnipeg, MA.

National Park Service. 1984. Wrangell St. Elias National Park and Preserve - Sensitive Wildlife Habitats 2. Paper map at 1:1,000,000. USDI National Park Service, Anchorage, AK.

Parks Canada. 1980. Kluane National Park Reserve Critical Wildlife Habitat - Dall Sheep. Paper map at 1:1,000,000. Environment Canada, Parks Canada - Prairie and Northern Region, Winnipeg, MA.

USDI Alaska Planning Group. 1975. Proposed Wrangell-St. Elias National Park - Dall Sheep Range. Paper map at 1:1,000,000. United States Department of the Interior, Anchorage, AK.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping

YDRR (Yukon Department of Renewable Resources). 1997. Yukon Key Wildlife Habitat. Digital map series at 1:250,000 scale. Yukon Department of Renewable Resources, GIS Unit, Whitehorse, YT.

Data Structure (4 Fields)
i. *Species* which is mapped (i.e. Dall Sheep)

ii. *Function* of the habitat (in this case, only general range is mapped)
iii. *Scale* of the source information
iv. *Source* from list above

Methods and Miscellaneous Notes

ADF&G (1973), Demarchi and Stewart (1974), Gray (1987), and YDRR (1997) served as primary map sources for this layer while the remaining sources were consulted for additional information and support during map creation. The first three sources were hand-digitized. Significant variations in habitat polygons that were identified as being a result of small map scale, and supported by additional references, were corrected by way of matching polygon edges to features on the digitized 1:250,000 UTM topographic map sheets. Edge matching was undertaken only when it was readily evident that two habitat patches comprised one continuous patch.

Habitat in Yukon beyond Kluane National Park was mapped by using YDRR (1997) digital key habitat data in combination with UTM topographic map sheets. The key habitat data was used as a base layer. Forest layers from the UTM map quadrangles were then superimposed to identify non-forested habitat areas where key habitat exists. The entire habitat patch was then copied from the forest layer and pasted to the Dall sheep layer. Adjacent alpine/subalpine areas without key habitat were included only when they exceeded 100 km^2. This method was carried out under the suggestion of Jean Carey, Yukon Dall sheep biologist.

The map sheet covering British Columbia (Demarchi and Stewart, 1974) was very generalized for this species. As such, some adjustments were made in order to facilitate a more uniform scale of mapping. Large glaciers, large forest blocks, and large bodies of water were eliminated from habitat polygons. Where it was deemed appropriate, polygon edges were matched to UTM quadrangle features such as contour lines, shorelines, and forest or glacier edges.

Each of the sources are based on observational data - not simply habitat capability. As such, habitat patches represent areas which are capable of supporting a population of Dall sheep and which have supported a population at sometime within the past 30 years.

FALL AND WINTER MOOSE CONCENTRATION

(st_elias/region/wildlife/moose_h.*)

Sources

ADF&G (Alaska Department of Fish and Game). 1973. Alaska's Fish and Wildlife. Paper maps generated at 1:250,000 and reduced to 1:1,000,000. Alaska Department of Fish and Game, Habitat Branch, Juneau, AK.

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

Gray, B. 1987. Kluane National Park Resource Description and Analysis. Important Wildlife Habitat Areas 2. Paper map at 1:500,000. Parks Canada, Prairie and Northern Region, Winnipeg, MA.

National Park Service. 1984. Wrangell St. Elias National Park and Preserve - Sensitive Wildlife Habitats 2. Paper map at 1:1,000,000. USDI National Park Service, Anchorage, AK.

Parks Canada. 1980. Kluane National Park Reserve Critical Wildlife Habitat - Moose, Wolf, Caribou. Paper map at 1:1,000,000. Environment Canada, Parks Canada - Prairie and Northern Region, Winnipeg, MA.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping
YDRR (Yukon Department of Renewable Resources). 1997. Yukon Key Wildlife Habitat. Digital map series at 1:250,000 scale. Yukon Department of Renewable Resources, GIS Unit, Whitehorse, YT.

Data Structure (5 Fields)

i. *Species* which is mapped (i.e. Moose)
ii. *Function1* represents general habitat function (fall concentration, winter concentration, fall and winter concentration)
iii. *Function2* represents specific habitat function (rutting area, fall concentration, winter concentration, fall and winter concentration, late winter range)
iv. *Source* of the information
v. *Scale* of the source information

Methods and Miscellaneous Notes

ADF&G (1973), Gray (1987), and YDRR (1997) served as primary map sources for this layer while the remaining sources were consulted for additional information and support during map creation. The first two sources were hand-digitized. Significant variations in habitat polygons that were identified as being a result of small map scale, and supported by additional references, were corrected by way of matching polygon edges to features on the digitized 1:250,000 UTM topographic map sheets. Edge matching was undertaken only when it was readily evident that two habitat patches comprised one continuous patch.

Information for British Columbia was inferred through textual references pertaining to the Tatshenshini-Alsek Wilderness Provincial Park and known moose habitat requirements. Further work should be carried out to identify key moose habitat in this area by way of aerial and ground surveys.

MOUNTAIN GOAT RANGE
(st_elias/region/wildlife/goat_r.*)

Sources
ADF&G (Alaska Department of Fish and Game). 1973. Alaska's Fish and Wildlife. Paper maps generated at 1:250,000 and reduced to 1:1,000,000. Alaska Department of Fish and Game, Habitat Branch, Juneau, AK.

BC Fish and Wildlife. 1978. The Approximate Distribution and Density of Mountain Goat Populations in British Columbia. Paper map at 1: 5,000,000. BC Fish and Wildlife Branch and BC Surveys and Mapping Branch, Victoria, BC.

EMRC (Energy Mines and Resources Canada). Various Dates. 1:250,000 Topographic Map Series. Aishihik Lake, Dezadeash River, Kluane Lake, Mt. St. Elias, Skagway, Snag, and Tatshenshini map sheets. Canada Centre for Mapping, EMRC, Ottawa, ON.

Gray, B. 1987. Kluane National Park Resource Description and Analysis. Important Wildlife Habitat Areas (1). Paper map at 1:500,000. Parks Canada, Prairie and Northern Region, Winnipeg, MA.

National Park Service. 1984. Wrangell St. Elias National Park and Preserve - Sensitive Wildlife Habitats 2 (paper copy). 1:1,000,000. USDI National Park Service, Anchorage, AK.

Parks Canada. 1980. Kluane National Park Reserve Critical Wildlife Habitat - Mountain Goat. Paper map at 1:1,000,000. Environment Canada, Parks Canada - Prairie and Northern Region, Winnipeg, MA.

USDI Alaska Planning Group. 1975. Proposed Wrangell-St. Elias National Park - Caribou, Bison, and Mountain Goat Range. Paper map at 1:1,000,000. United States Department of the Interior, Anchorage, AK.

USGS (US Geological Survey). Various Dates. 1:250,000 Topographic Map Series. Bering Glacier, Cordova, Gulkana, Icy Bay, Juneau, McCarthy, Middleton Island, Mt. Fairweather, Nabesna, Tanacross, Valdez, and Yakutat map sheets. Surveys and Mapping

YDRR (Yukon Department of Renewable Resources). 1997. Yukon Key Wildlife Habitat. Digital map series at 1:250,000 scale. Yukon Department of Renewable Resources, GIS Unit, Whitehorse, YT.

Data Structure (4 Fields)
i. *Species* which is mapped (i.e. Mountain Goat)

ii. *Function* represents general habitat function (in this case, general range only)
iii. *Source* of the information
iv. *Scale* of the source information

Methods and Miscellaneous Notes

ADF&G (1973), BC Fish and Wildlife (1978), and YDRR (1997) served as primary map sources for this layer while the remaining sources were consulted for additional information and support during map creation. The first two sources were hand-digitized. Significant variations in habitat polygons that were identified as being a result of small map scale, and supported by additional references, were corrected by way of matching polygon edges to features on the digitized 1:250,000 UTM topographic map sheets. Edge matching was undertaken only when it was readily evident that two habitat patches comprised one continuous patch.

The map sheets covering southeast Alaska in ADF&G (1973) were very general for this species, as was the map of British Columbia (BC F&W, 1978). As such, some adjustments were made in order to facilitate a more uniform scale of mapping. Large glaciers, large forest blocks, and large bodies of water were eliminated from habitat polygons. Where it was deemed appropriate, polygon edges were matched to UTM quadrangle features such as contour lines, shorelines, and forest or glacier edges.

Each of the sources are based on observational data - not simply habitat capability. As such, habitat patches represent areas which are capable of supporting mountain goats and which have supported more than simply “stray” individuals at sometime in the past 30 years.

CARIBOU HERDS AND KEY HABITAT
(st_elias/region/wildlife/carbou_r.*)

Sources

ADF&G (Alaska Department of Fish and Game). 1973. Alaska's Fish and Wildlife. Paper maps generated at 1:250,000 and reduced to 1:1,000,000. Alaska Department of Fish and Game, Habitat Branch, Juneau, AK.

Lenart, E.A. 1997. Effects of Weather on Caribou Forage Productivity and Nutrition within the Range of the Chisana Herd. Final Research Report. Includes paper map at 1:2,500,000. Alaska Department of Fish and Game, Division of Wildlife Conservation, Juneau, AK.

Lieb, J.W., W.B. Cella, and R.W. Tobey. 1994. Population Dynamics of the Mentasta Caribou Herd. Final Research Report. Includes paper map at 1:1,000,000. Alaska Department of Fish and Game, Division of Wildlife Conservation, Juneau, AK.

National Park Service. 1984. Wrangell St. Elias National Park and Preserve - Sensitive Wildlife Habitats 1 (paper copy). 1:1,000,000. USDI National Park Service, Anchorage, AK.

Strauch, B. 1998. Caribou Herds of Alaska. Digital Map at 1:2,500,000. Alaska Department of Fish and Game, Habitat Branch, Anchorage, AK.

USDI Alaska Planning Group. 1975. Proposed Wrangell-St. Elias National Park - Caribou, Bison, and Mountain Goat Range. Paper map at 1:1,000,000. United States Department of the Interior, Anchorage, AK.

YDRR (Yukon Department of Renewable Resources). 1997. Yukon Key Wildlife Habitat. Digital map series at 1:250,000 scale. Yukon Department of Renewable Resources, GIS Unit, Whitehorse, YT.

Data Structure (5 Fields)

i. *Taxon* (i.e. barren-ground or woodland caribou)
ii. *Population* identifies which herd is mapped
iii. *Function* represents specific habitat function (rutting area, wintering area, total herd range, extended herd range, primary herd range, calving area, summer range)
iv. *Source* of the information
v. *Scale* of the source information

Methods and Miscellaneous Notes

Strauch (1998) and YDRR (1997) served as the primary general map sources for this layer as they each identified habitat for all herds relative to the study area. NPS (1984), Lieb *et al.* (1994) and Lenart (1997) were consulted for maps relating to specific herds. The remaining sources were consulted for additional support during map creation. Mapping of total herd range for Yukon herds was available only at 1:5,000,000.

Some inconsistencies in range and key habitat mapping were found to exist between sources for the Mentasta and Chisana caribou herds. This was primarily related to different classifications of range. As a result, range for these two herds was divided into two classifications: primary range and extended range, wherein the primary range is utilized most often, but it is not unusual for the herd to be located within the extended range.

In addition, different habitat areas are considered key or critical by different agencies or investigators. This results in the fact that different habitat areas have been mapped for different herds. For example, rutting areas have been identified for the Yukon herds but not the Alaskan herds. Conversely, calving areas have been identified for the Alaskan-based woodland herds but not the Yukon woodland herds.

GRIZZLY BEAR KEY HABITAT

(st_elias/region/wildlife/bear.*)

Sources

ADF&G (Alaska Department of Fish and Game). 1973. Alaska's Fish and Wildlife. Paper maps generated at 1:250,000 and reduced to 1:1,000,000. Alaska Department of Fish and Game, Habitat Branch, Juneau, AK.

Herrero, S, A.H. Weerstra, R.M. Roth, and L. Wiggins. 1993. *The Conservation Significance of Bears and Their Habitat in the Tatshenshini River Valley*. Report prepared by the University of Calgary Faculty of environmental Design for the Canadian Wildlife Federation, Ottawa, ON.

National Park Service. 1984. Wrangell St. Elias National Park and Preserve - Sensitive Wildlife Habitats 1 (paper copy). 1:1,000,000. USDI National Park Service, Anchorage, AK.

YDRR (Yukon Department of Renewable Resources). 1997. Yukon Key Wildlife Habitat. Digital map series at 1:250,000 scale. Yukon Department of Renewable Resources, GIS Unit, Whitehorse, YT.

Data Structure (5 Fields)

i. *Species* which is mapped (i.e. Grizzly Bear)

ii. *Function* represents habitat function of the polygon (i.e. key habitat in Yukon and British Columbia; fish stream concentrations, intensive use areas, and known denning concentrations in Alaska)

iii. *Source* of the information

iv. *Scale* of the source information

Methods and Miscellaneous Notes

One of the primary difficulties in mapping key grizzly bear habitat is the fact that different habitat areas are considered key or critical by different agencies or investigators. This results in the fact that key habitat areas are based on different factors in the Yukon, British Columbia, and Alaska. Moreover, from a continental and even global perspective, much of the St. Elias region could be considered key brown/grizzly bear habitat, making the selection of certain areas over others rather controversial.

It is clearly evident from an examination of the written literature surrounding grizzly bears in the region that more detailed mapping is required for this species. As such, this map layer should be used only as a guide in the evaluation of where more investigations are required, rather than as a definitive statement on the ecology of this species.

SURVEYED WILDLIFE DENSITIES
(st_elias/region/wildlife/sheep_d.*, goat_d.*, moose_.*)

Sheep Data Sources

McKinnon, C. 1996. Donjek Dall Sheep Survey, 1996. Parks Canada Warden Service Report on file at Kluane National Park Reserve, Haines Junction, YT.

Larocque, L. 1987. Auriol Range Dall Sheep and Goat Survey, 1987. Parks Canada Warden Service Report on file at Kluane National Park Reserve, Haines Junction, YT.

McKinnon, C. 1996. Vulcan Mountain Dall Sheep Survey, 1996. Parks Canada Warden Service Report on file at Kluane National Park Reserve, Haines Junction, YT.

McKinnon, C. 1996. Sheep Mountain Dall Sheep Survey, 1996. Parks Canada Warden Service Report on file at Kluane National Park Reserve, Haines Junction, YT.

Strickland, D., L.L. McDonald, D. Taylor, K. Jenkins, J. Kern. 1992. Estimation of Dall Sheep Numbers in the Wrangell-St. Elias National Park and Preserve. In; J. Emmerich and W.G. Hepworth (eds.), *Proceedings of the 8th Biennial Symposium of the Northern Wild Sheep and Goat Council*. pp. 237-255. Northern Wild Sheep and Goat Council, Helena, MT.

Carey, J., R. Sumanik, and B.J. Bjorn. 1989. Sheep Lambing Survey of Mt. Wellgreen and Vicinity, June 1989. Parks Canada-YTG Joint Report on File at Kluane National Park Reserve, Haines Junction, YT.

Barichello, N. and J. Carey. 1988. Thinhorn Sheep Status and Management in the Yukon. Yukon Department of Renewable Resources, Whitehorse, YT.

Mountain Goat Data Sources

Dolsen, J. 1997. Goatherd Mountain Mountain Goat Survey, 1997. Parks Canada Warden Service Report on file at Kluane National Park Reserve, Haines Junction, YT.

Larocque, L. 1987. Auriol Range Dall Sheep and Goat Survey, 1987. Parks Canada Warden Service Report on file at Kluane National Park Reserve, Haines Junction, YT.

Moose Data Sources

Ward, R.M.P. and D.G. Larsen. 1995. *Summary of 1992 Moose Surveys in the Aishihik, Onion Creek, Big Salmon, Mayo, and Dawson Areas*. PR-95-02. Yukon Renewable Resources, Fish and Wildlife Branch, Whitehorse, Yukon.

Data Structure (4 Fields, 3 Tables)

i. *Area* refers to the name of the survey unit (e.g. Kluane National Park - Auriol

Range, or Northwest Wrangell Mountains)

ii. *GMU* refers to the conservation unit in which the survey are lies. A state or territorial game management unit code is given for areas located outside of parks and protected areas.

iii. *Density* of the species is given in the number of individuals per square kilometre.

iv. *Source* of the information (as per the list above).

Methods and Miscellaneous Notes

Population density is often used to assess the relative quality of habitat for a given species as well as changes in the health of a population over time. The use of density rather than total survey counts facilitates comparison between populations. Density estimates were collected for each of Dall sheep, mountain goat, and moose from published sources and internal research reports. In many cases these estimates were based simply on dividing the total number of individuals observed during a given survey by the area covered during that survey. Occasionally, additional factors such as search effort, visibility, and seasonal variables were also considered. An attempt was made to standardize all density estimates based on the former method if the appropriate information (i.e. total survey area and total count) was given. Moreover, an attempt was made to standardize densities based on a common demographic (i.e. excluding young of the year). For the purposes of display, an average density was calculated in cases where multiple years of data was available.

APPENDIX D

MISCELLANEOUS LANDCOVER AND VEGETATION DATA

Table C1: Breakdown of Ecosystem Types Represented in Alaskan Portions of the St. Elias Region

	Percent of Total Area Occupied by Ecosystem Type						
Ecosystem Type	WRST	GLBA	TETLIN	Yakutat Block	Icy Bay to Valdez	Copper River Watershed (unprotected portions)	Lynn Canal
Alpine Tundra (including permanent snow and ice)	70.9	76.1	3.9	66.3	69	30.4	67.5
Moist Tundra	2.1					9.8	
Wet Tundra		0.1		9.8	6.4		
High Brush	4.6		2.7		1	1.4	
Low Brush, Muskeg-Bog	0.4		26.8			1	
Lowland Spruce-Hardwood Forest	5.7		41.8			33.3	
Bottomland Spruce-Poplar Forest	1.2					1.2	
Upland Spruce-Hardwood Forest	13.5		24.7			22.3	
Costal Rain Forest	1.6	23.8		23.9	23.6	0.1	32.5

Table C2: Basic Landcover in the St. Elias Region

		Percent of Total Area					
	Total Area (km)	Permanent Snow and Ice	Isolated Alpine Nunataks	Forest	Open Water(1)	Major Wetlands	Other(2)
Kluane National Park	22013	52.4	11.5	7.5	0.8	0.2	27.6
Wrangell-St. Elias National Park	53420	35.2	5.6	18.7	1.3	0.1	39.2
Glacier Bay National Park	13355	30.9	9.1	20.3	19.5	0.0	20.3
Tatshenshini-Alsek Wilderness	9580	37.9	6.8	8.5	0.6	0.0	46.2
Tetlin National Wildlife Refuge	3739	0.1	0	61.6	6.3	18.5	13.5
Kluane Wildlife Sanctuary	6368	10.3	2.1	42.8	0.6	0.2	44.0
Yakutat Block (Tongass NF)	5273	35.7	6.3	24.0	6.5	4.1	23.3
Icy Bay to Valdez	15550	36.9	4.5	21	6.5	5.1	26
Copper River Watershed (unprotected portions east of 147°)	21710	5.4	0.4	34.6	3.8	1	54.9
Lynn Canal Area	13180	28.6	3.8	28.4	13.9	0	25.2
Shakwak Trench & Kluane Plateau	23480	0.0	0.0	74.7	4.3	0.6	20.4

(1) Includes marine bays and inlets
(2) Primarily alpine and subalpine shrub, grass, and forbs, but unidentifiable at this scale.

Table C3: Landcover in the Tetlin NWR

Cover Type	Hectares	Percent of Total
Closed Needleleaf Forest (dominated by white spruce)	36342	9.7
Open Needleleaf Forest (dominated by black spruce)	80100	21.4
Needleleaf Woodland	106861	28.5
Mixed Forest (white spruce, white birch, and aspen)	12940	3.5
Deciduous Forest (white birch, aspen, and balsam poplar)	6551	1.7
Lowland Deciduous Scrub (willow and other deciduous shrubs)	2509	0.7
Alpine and Subalpine Deciduous Scrub (willow and dwarf birch)	14986	4
Prostrate Dwarf Scrub (matted dwarf alpine shrubs, particularly white mountain-avens)	1773	0.5
Dwarf Scrub/Graminoid Tussock Peatland	77009	20.6
Graminoid Marsh/Alluvial Scrub (intermittent wetland of various sedges, grasses and forbes)	6431	1.7
Sparsely Vegetated and Barren Screes	5798	1.5
Sparsely Vegetated and Barren Floodplains	5034	1.3
Clear Water	11712	3.1
Shallow Low Sedimented Water/Aquatic Vegetation	3536	0.9
Medium-High Sedimented Water	2592	0.7
Snow	280	<0.1
Totals	374453	100

Table C4: Landcover Categories of Wrangell-St. Elias NPP

Water
Barren
Glacier/Snow
Closed White Spruce
Open White Spruce
White Spruce Woodland
Closed Black Spruce
Open Black Spruce
Black Spruce Woodland
Closed Black Spruce/White Spruce Mix
Open Black Spruce/White Spruce Mix
Black Spruce/White Spruce Woodland
Closed Broadleaf
Open Broadleaf
Closed Black Spruce/White Spruce/Broadleaf Mix
Open Black Spruce/White Spruce/Broadleaf Mix
Closed Tall Alder
Open Tall Alder
Closed Tall Willow
Open Tall Willow
Closed Tall Alder/Willow Mix
Open Tall Alder/Willow Mix
Closed Tall Shrub
Open Tall Shrub
Closed Low Shrub
Open Low Shrub
Dwarf Shrub Tundra
Sparse Dwarf Shrub Tundra
Graminoid
Forb
Wet Moss/Lichen
Dry Moss/Lichen
Sparse Vegetation
Clouds/Cloud Shadow

APPENDIX E

SPECIES LISTS
AND
METADATA

TABLE D1
BIRDS OF THE ST. ELIAS MOUNTAIN PARKS AND TETLIN NWR

B	Confirmed breeding within park boundaries
b	Probable breeding within park boundaries
(b)	Possible breeding within park boundaries
o	Observed somewhat regularly, but not suspected to breed
m	Transient migrant that occurs regularly
p	Palaegic species often seen near or on shore
w	The park is distinct winter habitat for a species
i/c	Incidental/Casual

GAVIIFORMES		**WRST**	**KNP**	**GLBA**	**TAT**	**TETLIN**
GAVIIDAE						
Gavia stellata	Red-throated Loon	(b)	(b)	B	b	i/c
Gavia pacifica	Pacific Loon	B	(b)	w	(b)	B
Gavia immer	Common Loon	b	B	b	b	B
Gavia adamsii	Yellow-billed Loon	w		w		
PODICIPEDIFORMES						
PODICIPEDIDAE						
Podilymbus podiceps	Pied-billed Grebe		i/c			
Podiceps auritus	Horned Grebe	b	B	w	o	B
Podiceps grisegena	Red-necked Grebe	B	(b)	w		B
Aechmophorus occidentalis	Western Grebe			i/c		
PROCELLARIIFORMES						
DIOMEDEIDAE						
Phoebastria nigripes	Black-footed Albatross			p		
PROCELLARIIDAE						
Fulmarus glacialis	Northern Fulmar			p		
Puffinus carneipes	Flesh-footed Shearwater			p		
Puffinus griseus	Sooty Shearwater			p		
Puffinus tenuirostris	Short-tailed Shearwater			p		
HYDROBATIDAE						
Oceanodroma furcata	Fork-tailed Storm-Petrel			B		
Oceanodroma leucorhoa	Leach's Storm-Petrel			(b)		
PELECANIFORMES						
PHALACROCORACIDAE						
Phalacrocorax auritus	Double-crested Cormorant	b		(b)		i/c
Phalacrocorax pelagicus	Pelagic Cormorant	b		B		

CICONIIFORMES

ARDEIDAE

Botaurus lentiginosus	American Bittern			i/c		
Ardea herodias	Great Blue Heron	(b)		B	o	
Ardea alba	Great Egret			i/c		

CATHARTIDAE

Cathartes aura	Turkey Vulture					i/c

ANSERIFORMES

ANATIDAE

Anser albifrons	G. White-fronted Goose	m	m	m		m
Chen canagica	Emperor Goose			i/c		
Chen caerulescens	Snow Goose	m	m	m	m	i/c
Branta canadensis	Canada Goose	B	B	B	(b)	B
Branta bernicla	Brant	m		m		i/c
Cygnus buccinator	Trumpeter Swan	B	B	m	b	B
Cygnus columbianus	Tundra Swan	m	m	m		m
Anas strepera	Gadwall			w		(b)
Anas penelope	Eurasian Wigeon	i/c		i/c		
Anas americana	American Wigeon	B	(b)	(b)		B
Anas rubripes	American Black Duck			i/c		
Anas platyrhynchos	Mallard	B	B	B	b	B
Anas discors	Blue-winged Teal	(b)	(b)	m	(b)	B
Anas cyanoptera	Cinnamon Teal		i/c	i/c	i/c	i/c
Anas clypeata	Northern Shoveler	b	b	b	(b)	B
Anas acuta	Northern Pintail	b	B	B	b	B
Anas crecca	Green-winged Teal	B	B	B	b	B
Aythya valisineria	Canvasback	(b)	(b)	m	b	B
Aythya americana	Redhead	(b)	i/c	i/c	(b)	(b)
Aythya collaris	Ring-necked Duck	b		m	o	B
Aythya marila	Greater Scaup	b	B	m	(b)	B
Aythya affinis	Lesser Scaup	b	B	B	b	B
Somateria spectabilis	King Eider			m		
Somateria mollissima	Common Eider			B		
Histrionicus histrionicus	Harlequin Duck	B	b	B	(b)	(b)
Melanitta perspicillata	Surf Scoter	b	B	w	(b)	B
Melanitta fusca	White-winged Scoter	b	B	w	b	B
Melanitta nigra	Black Scoter	o	m	w		
Clangula hyemalis	Oldsquaw	o	m	b	o	i/c
Bucephala albeola	Bufflehead	B	B	(b)	o	B
Bucephala clangula	Common Goldeneye	b	B	w	b	B
Bucephala islandica	Barrow's Goldeneye	B	B	B	b	B
Lophodytes cucullatus	Hooded Merganser			B		

Mergus merganser	Common Merganser	b	B	B	b	i/c
Mergus serrator	Red-breasted Merganser	B	b	B	(b)	i/c
Oxyura jamaicensis	Ruddy Duck		i/c		(b)	B
FALCONIFORMES						
ACCIPITRIDAE						
Pandion haliaetus	Osprey		(b)	m	(b)	B
Haliaeetus leucocephalus	Bald Eagle	B	B	B	b	B
Circus cyaneus	Northern Harrier	b	b	m	(b)	(b)
Accipiter striatus	Sharp-shinned Hawk	B	B	B	b	B
Accipiter gentilis	Northern Goshawk	B	B	B	b	B
Buteo swainsoni	Swainson's Hawk	i/c	m	m		i/c
Buteo jamaicensis	Red-tailed Hawk	B	B	B	b	B
Buteo lagopus	Rough-legged Hawk	m	m	m	m	m
Aquila chrysaetos	Golden Eagle	B	B	(b)	b	B
FALCONIDAE						
Falco sparverius	American Kestrel	(b)	B	m	b	B
Falco columbarius	Merlin	B	B	m	(b)	B
Falco rusticolus	Gyrfalcon	B	B		b	b
Falco peregrinus	Peregrine Falcon	(b)	B	B	(b)	B
GALLIFORMES						
PHASIANIDAE						
Bonasa umbellus	Ruffed Grouse	(b)	B			B
Falcipennis canadensis	Spruce Grouse	B	B		b	B
Lagopus lagopus	Willow Ptarmigan	B	B	B	b	B
Lagopus mutus	Rock Ptarmigan	b	B	B	b	(b)
Lagopus leucurus	White-tailed Ptarmigan	(b)	B	B	b	(b)
Dendragapus obscurus	Blue Grouse			B	b	
Tympanuchus phasianellus	Sharp-tailed Grouse	b				B
GRUIFORMES						
RALLIDAE						
Porzana carolina	Sora				o	(b)
Fulica americana	American Coot	i/c	i/c	m		B
GRUIDAE						
Grus canadensis	Sandhill Crane	o	m	m	o	B
CHARADRIIFORMES						
CHARADRIIDAE						
Pluvialis squatarola	Black-bellied Plover			m		i/c
Pluvialis dominica	American Golden-Plover		B	m	o	B
Pluvialis fulva	Pacific Golden-Plover	m				
Charadrius semipalmatus	Semipalmated Plover	b	B	B	b	B
Charadrius vociferus	Killdeer	(b)	(b)	b	o	(b)
HAEMATOPODIDAE						

Haematopus bachmani	Black Oystercatcher	b		B		
SCOLOPACIDAE						
Tringa melanoleuca	Greater Yellowlegs	B	i/c	B	b	i/c
Tringa flavipes	Lesser Yellowlegs	b	B	B	b	B
Tringa solitaria	Solitary Sandpiper	B	(b)	B	(b)	B
Heteroscelus incanus	Wandering Tattler	(b)	b	(b)	b	(b)
Actitis macularia	Spotted Sandpiper	B	B	B	b	B
Bartramia longicauda	Upland Sandpiper	B	(b)	i/c	o	(b)
Numenius phaeopus	Whimbrel	(b)		m	o	B
Numenius tahitiensis	Bristle-thighed Curlew			i/c		
Limosa haemastica	Hudsonian Godwit			m	b	i/c
Limosa lapponica	Bar-tailed Godwit			i/c		
Limosa fedoa	Marbled Godwit			m		
Arenaria interpres	Ruddy Turnstone			m		i/c
Arenaria melanocephala	Black Turnstone	i/c		m		i/c
Aphriza virgata	Surfbird	B		m		i/c
Calidris canutus	Red Knot	i/c		m		
Calidris alba	Sanderling	w	m	w		
Calidris pusilla	Semipalmated Sandpiper	m	m	m	m	m
Calidris mauri	Western Sandpiper	m		m	m	m
Calidris ruficollis	Red-necked Stint			i/c		
Calidris minutilla	Least Sandpiper	b	B	B	b	(b)
Calidris bairdii	Baird's Sandpiper	m		m	m	m
Calidris melanotos	Pectoral Sandpiper	m	i/c	m	m	m
Calidris ptilocnemis	Rock Sandpiper			w		
Calidris alpina	Dunlin	i/c	i/c	m	m	
Tryngites subruficollis	Buff-breasted Sandpiper			i/c		i/c
Limnodromus griseus	Short-billed Dowitcher		(b)	m	b	i/c
Limnodromus scolopaceus	Long-billed Dowitcher	m		m	m	m
Gallinago gallinago	Common Snipe	B		B	b	B
Phalaropus lobatus	Red-necked Phalarope	b	B	(b)	b	B
Phalaropus fulicaria	Red Phalarope	i/c		i/c		
LARIDAE						
Catharacta maccormicki	South Polar Skua			i/c		
Stercorarius pomarinus	Pomarine Jaeger	i/c		m		
Stercorarius parasiticus	Parasitic Jaeger	B		B		i/c
Stercorarius longicaudus	Long-tailed Jaeger	o	B	m		i/c
Larus ridibundus	Black-headed Gull					i/c
Larus philadelphia	Bonaparte's Gull	(b)	B	(b)	b	B
Larus canus	Mew Gull	B	B	B	b	B
Larus delawarensis	Ring-billed Gull	o				
Larus argentatus	Herring Gull	B	B	B	b	i/c
Larus thayeri	Thayer's Gull			b		

Larus glaucescens	Glaucous-winged Gull	b	i/c	B		i/c
Larus hyperboreus	Glaucous Gull			m	m	i/c
Xema sabini	Sabine's Gull	i/c		m		i/c
Rissa tridactyla	Black-legged Kittiwake	(b)		B		
Rhodostethia rosea	Ross's Gull			i/c		
Pagophila eburnea	Ivory Gull			i/c		
Sterna caspia	Caspian Tern			i/c		
Sterna hirundo	Common Tern			i/c		
Sterna paradisaea	Arctic Tern	B	B	B	b	B
Sterna aleutica	Aleutian Tern	(b)		B		
Chlidonias niger	Black Tern					i/c

ALCIDAE

Uria aalge	Common Murre	(b)		B		
Cepphus columba	Pigeon Guillemot	(b)		B		
Brachyramphus marmoratus	Marbled Murrelet	b		b		
Brachyramphus brevirostris	Kittlitz's Murrelet	b		b		
Synthliboramphus antiquus	Ancient Murrelet	(b)		o		
Ptychoramphus aleuticus	Cassin's Auklet			m		
Aethia psittacula	Parakeet Auklet			i/c		
Aethia cristatella	Crested Auklet	i/c				
Cerorhinca monocerata	Rhinoceros Auklet			m		
Fratercula corniculata	Horned Puffin			B		
Fratercula cirrhata	Tufted Puffin			B		

COLUMBIFORMES

COLUMBIDAE

Columba livia	Rock Dove				o	i/c
Columba fasciata	Band-tailed Pigeon			i/c		
Zenaida macroura	Mourning Dove	i/c	i/c	i/c		

STRIGIFORMES

STRIGIDAE

Otus kennicottii	Western Screech-Owl			i/c		
Bubo virginianus	Great Horned Owl	B	B	(b)	(b)	B
Nyctea scandiaca	Snowy Owl	w	w	i/c	m	i/c
Surnia ulula	Northern Hawk Owl	B	B		b	B
Strix nebulosa	Great Gray Owl	(b)	(b)			B
Asio flammeus	Short-eared Owl	B	b	(b)	(b)	(b)
Aegolius funereus	Boreal Owl	b	b	i/c		B
Aegolius acadicus	Saw-whet Owl				o	

CAPRIMULGIFORMES

CAPRIMULGIDAE

Chordeiles minor	Common Nighthawk		b	i/c	(b)	i/c

APODIFORMES

APODIDAE						
Chaetura vauxi	Vaux's Swift			i/c		
TROCHILIDAE						
Calypte anna	Anna's Hummingbird					i/c
Selasphorus rufus	Rufous Hummingbird	b	i/c	B	(b)	
CORACIIFORMES						
ALCEDINIDAE						
Ceryle alcyon	Belted Kingfisher	B	(b)	B	b	B
PICIFORMES						
PICIDAE						
Sphyrapicus varius	Yellow-bellied Sapsucker					(b)
Sphyrapicus ruber	Red-breasted Sapsucker	i/c		i/c	b	i/c
Picoides pubescens	Downy Woodpecker	B	(b)	i/c	(b)	i/c
Picoides villosus	Hairy Woodpecker	B	(b)	b	b	b
Picoides tridactylus	Three-toed Woodpecker	B	B	B	(b)	b
Picoides arcticus	Black-backed Woodpecker	b	B		(b)	b
Colaptes auratus	Northern Flicker	B	B	B	b	B
PASSERIFORMES						
TYRANNIDAE						
Contopus cooperi	Olive-sided Flycatcher	(b)	b	(b)	(b)	(b)
Contopus sordidulus	Western Wood-Pewee	B	b	(b)	(b)	(b)
Empidonax flaviventris	Yellow-bellied Flycatcher					i/c
Empidonax alnorum	Alder Flycatcher	b	B	b	(b)	B
Empidonax minimus	Least Flycatcher		(b)		(b)	i/c
Empidonax hammondii	Hammond's Flycatcher	(b)	i/c	i/c	(b)	i/c
Empidonax oberholseri	Dusky Flycatcher		i/c		(b)	
Empidonax difficilis	Pacific-slope Flycatcher			b		
Sayornis phoebe	Eastern Phoebe		i/c			
Sayornis saya	Say's Phoebe	B	B	b	b	(b)
Tyrannus tyrannus	Eastern Kingbird		i/c	i/c		
Tyrannus forficatus	Scissor-tailed Flycatcher			i/c		
LANIIDAE						
Lanius excubitor	Northern Shrike	(b)	(b)	w	b	b
VIREONIDAE						
Vireo solitarius	Blue-headed Vireo		i/c			
Vireo gilvus	Warbling Vireo				o	i/c
CORVIDAE						
Perisoreus canadensis	Gray Jay	B	B	o	b	B
Cyanocitta stelleri	Steller's Jay	i/c	(b)	B	(b)	
Nucifraga columbiana	Clark's Nutcracker		i/c	i/c		
Pica pica	Black-billed Magpie	b	B	o	b	b

Corvus caurinus	Northwestern Crow		i/c	B		
Corvus corax	Common Raven	B	B	B	b	B
ALAUDIDAE						
Eremophila alpestris	Horned Lark	b	B	m	b	(b)
HIRUNDINIDAE						
Tachycineta bicolor	Tree Swallow	B	B	B	b	B
Tachycineta thalassina	Violet-green Swallow	B	B	B	b	B
Stelgidopteryx serripennis	Rough-winged Swallow				o	
Riparia riparia	Bank Swallow	B	B	B	b	B
Petrochelidon pyrrhonota	Cliff Swallow	B	B	m	b	B
Hirundo rustica	Barn Swallow	B	B	B	b	(b)
PARIDAE						
Poecile atricapillus	Black-capped Chickadee	b	b	i/c	b	B
Poecile gambeli	Mountain Chickadee		i/c			
Poecile rufescens	Chestnut-backed Chickadee	b		B	(b)	
Poecile hudsonicus	Boreal Chickadee	B	B		b	B
Poecile cinctus	Siberian Tit					i/c
SITTIDAE						
Sitta canadensis	Red-breasted Nuthatch	b	(b)	m	b	i/c
CERTHIIDAE						
Certhia americana	Brown Creeper	(b)	i/c	b	o	i/c
TROGLODYTIDAE						
Troglodytes troglodytes	Winter Wren	(b)		B	b	
CINCLIDAE						
Cinclus mexicanus	American Dipper	B	b	B	(b)	b
REGULIDAE						
Regulus satrapa	Golden-crowned Kinglet	B	b	B	b	i/c
Regulus calendula	Ruby-crowned Kinglet	B	b	B	(b)	B
SYLVIIDAE						
Phylloscopus borealis	Arctic Warbler	(b)				i/c
TURDIDAE						
Oenanthe oenanthe	Northern Wheatear	B	(b)			i/c
Sialia currucoides	Mountain Bluebird	B	B	i/c	(b)	(b)
Myadestes townsendi	Townsend's Solitaire	B	B	i/c	b	(b)
Catharus minimus	Gray-cheeked Thrush	b	B	B	b	(b)
Catharus ustulatus	Swainson's Thrush	B	B	B	b	B
Catharus guttatus	Hermit Thrush	b	B	B	b	B
Turdus migratorius	American Robin	B	B	B	b	B
Ixoreus naevius	Varied Thrush	B	B	b	b	B
STURNIDAE						
Sturnus vulgaris	European Starling		B	o	(b)	(b)
MOTACILLIDAE						

Motacilla alba	White Wagtail			i/c		
Motacilla lugens	Black-backed Wagtail					i/c
Anthus rubescens	American Pipit	B	B	B	b	(b)
BOMBYCILLIDAE						
Bombycilla garrulus	Bohemian Waxwing	B	B	i/c	b	B
Bombycilla cedrorum	Cedar Waxwing				o	
PARULIDAE						
Vermivora peregrina	Tennessee Warbler		B		(b)	i/c
Vermivora celata	Orange-crowned Warbler	B	B	B	(b)	B
Dendroica petechia	Yellow Warbler	(b)	B	B	b	(b)
Dendroica coronata	Yellow-rumped Warbler	B	B	B	b	B
Dendroica townsendi	Townsend's Warbler	B		b	(b)	(b)
Dendroica palmarum	Palm Warbler		i/c			
Dendroica striata	Blackpoll Warbler	(b)	B	i/c	(b)	m
Setophaga ruticilla	American Redstart		B	i/c	b	
Seiurus noveboracensis	Northern Waterthrush	b	b		(b)	B
Oporornis tolmiei	MacGillivray's Warbler		(b)	i/c	(b)	
Geothlypis trichas	Common Yellowthroat		(b)	B	(b)	i/c
Wilsonia pusilla	Wilson's Warbler	b	B	B	b	(b)
THRAUPIDAE						
Piranga ludoviciana	Western Tanager		i/c	i/c		
EMBERIZIDAE						
Spizella arborea	American Tree Sparrow	B	B	m	b	B
Spizella passerina	Chipping Sparrow		B	i/c	(b)	B
Spizella pallida	Clay-colored Sparrow					i/c
Spizella breweri	Brewer's Sparrow	B	B		b	(b)
Chondestes grammacus	Lark Sparrow					i/c
Passerculus sandwichensis	Savannah Sparrow	B	B	B	b	B
Passerella iliaca	Fox Sparrow	b	B	B	b	B
Melospiza melodia	Song Sparrow	b	B	B	b	i/c
Melospiza lincolnii	Lincoln's Sparrow	B	B	B	(b)	B
Zonotrichia albicollis	White-throated Sparrow		i/c			i/c
Zonotrichia leucophrys	White-crowned Sparrow	B	B	m	b	B
Zonotrichia atricapilla	Golden-crowned Sparrow	b	B	B	b	i/c
Junco hyemalis	Dark-eyed Junco	B	B	B	b	B
Calcarius lapponicus	Lapland Longspur	b	m	m		m
Calcarius pictus	Smith's Longspur	B	(b)	i/c		(b)
Plectrophenax nivalis	Snow Bunting	b	B	B	b	m
ICTERIDAE						
Agelaius phoeniceus	Red-winged Blackbird	(b)	B	B	(b)	B
Sturnella neglecta	Western Meadowlark					i/c
Euphagus carolinus	Rusty Blackbird	b	B	B	(b)	B
Molothrus ater	Brown-headed Cowbird	i/c	i/c	i/c	i/c	i/c

FRINGILLIDAE

Fringilla montifringilla	Brambling	i/c				
Leucosticte tephrocotis	Gray-crowned Rosy-Finch	(b)	B	B	(b)	i/c
Pinicola enucleator	Pine Grosbeak	(b)	(b)	B	b	b
Carpodacus purpureus	Purple Finch		i/c			i/c
Loxia curvirostra	Red Crossbill	(b)	B	w		
Loxia leucoptera	White-winged Crossbill	b	B	w	b	B
Carduelis flammea	Common Redpoll	B	B	B	b	b
Carduelis hornemanni	Hoary Redpoll	w		i/c		w
Carduelis pinus	Pine Siskin	b	B	B	b	i/c

BIRD LIST METADATA

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Nomenclature

The American Ornithologists' Union (AOU) "Checklist of North American Birds" is the standard authority for avian taxonomy in North America and was used here. The 6th edition and its supplements was used.

Methods

The bird list was generated by combining information from the above noted references. However, this task was not as straightforward as it initially appears. While each of the primary protected areas maintains a species checklist, they are all in very different formats. For example, the lists for Glacier Bay and Wrangell St. Elias provide a breakdown of the relative abundance of a species on a seasonal basis, but denote little about the species' biological residency within the park (i.e. breeder, migrant, etc.). Another difficulty encountered when combining these lists was the various notations used for describing the relative abundance of a species. Terms and phrases such as "abundant", "common", "rare", "casual", "frequent", "rare but regular", "locally common", etc., are rather ambiguous in the absence of quantifiable descriptions, and are useless when attempting to aggregate data. For this reason, relative abundance was not incorporated into the aggregated species list. Species were grouped into the following categories:

B - Confirmed breeding within park boundaries
A species was assigned to this category when breeding has been confirmed within the park boundaries though observations related to nesting activities.

b - Probably breeding within park boundaries
A species was assigned to this category when breeding when breeding is highly probable but nests or fledged young have yet to be positively identified.

(b) - Potential breeding within park boundaries
A species was assigned to this category if it has been observed residing within a park during its breeding period and suitable breeding habitat is known to exist.

m - Transient migrant
A species was classified as a transient migrant if it utilizes the park during migration to and/or from breeding grounds.

p - Palaegic species often seen near or on shore
Palaegic species not known to breed within a park but often observed near shore were assigned to this category.

w - The park is distinct winter habitat for a species
Long distance migrants and nonmigrants utilizing a park only as part of its winter were assigned to this category.

i/c - Incidental/Casual
Species not placed in any of the above categories were considered incidental or casual. Incidental/casual species range from those occassionally observed within a park but not suspected of breeding within the park to accidental species far from the core of their global range.

A species was included on the list only when a confirmed observation had been made within the boundaries of the respective protected area. The following describes the specific methods used in assigning the status of a species from each park to the regional list:

Glacier Bay: The park's bird checklist (Paige, no date) served as the template for species occurance, and was supplemented by accounts from park staff. Any bird denoted with the symbols for "nests or unfledged young found" or "nesting suspected" were marked as breeding or probably breeding within the park. Any species present in significant numbers during the breeding season but where breeding has not been confirmed, and yet suitable breeding conditions exist, was assigned as a potential/possible breeder. Armstrong (1990) was used as a reference to determine whether or not a species should be considered a potential breeder or a casual visitor to the park.

Tatshenshini-Alsek: The report written by Lofroth and Mahon (1993) acted as the basic species list for Tatshenshini-Alsek Provincial Park. This report is based on field surveys undertaken during the summer of 1992 and summarizes all other species occurances previously noted for the park. Campbell *et al.* (1989) served as a valuable supporting reference for additional breeding accounts. However, due to its remote nature, breeding status has been confirmed for only a handful of species in this area. In instances where confirmed breeding records were absent, yet the park is located within a species' known continental breeding range (based on range maps by Godfrey, 1984 and Campbell *et al.*, 1989) *and* was noted as being common in suitable habitat by Lofroth and Mahon, or fledged young were observed, then the species was assigned to the "confirmed or probable breeder" category. A species was categorized as being a potential breeder if it has been observed within the park during breeding season (based on records in Campbell *et al.*, 1989), suitable breeding habitat exists within the park, and the park falls within the breeding range described by Godfrey (1984). Most observations in the Tatshenshini-Alsek area have been during the breeding season, explaining the relative lack of records for migrants and incidentals.

Kluane: Gray (1987) developed an annotated checklist for Kluane National Park based on all prior avian studies conducted in the area as well as range maps provided by Godfrey (1966). Species were categorized as positively breeding, probably breeding, migrant, or wanderer. However, examination of the annotations indicates that many of the breeding categorizations are actually based on observations that include the Kluane Wildlife Sanctuary. As a result, several modifications were made to Gray's list in order to confine records specifically to Kluane National Park. Where breeding has been confirmed in the Sanctuary but not in the Park the status of a species was dropped to *probable* or *potential* breeder. The differentiation between these two categories was made on the basis of relative abundance. When Gray noted a species as common, abundant, or frequent within the National Park, the species was considered a probable breeder. When a species was considered occassional or rare, yet breeding had been confirmed within the Sanctuary or immediately outside the Park, the species was categorized as a potential breeder.

Wrangell-St. Elias: ANHA's 1992 checklist of birds is the only compiled list of birds to have been completed for the Wrangell-St. Elias area. While it does list the relative abundance of individual species in different locations within the park at different times of the year, it does not indicate breeding status for any of these species. Subsequent searches revealed that confirmed breeding reports are very limited for Wrangell-St. Elias. Information on confirmed breeding was obtained from park biologist Carl Mitchell.

A species was considered a probable breeder when the ANHA checklist considered it to be common in the park and Armstrong (1990) and Scott (1987) identified the park within the species breeding range in Alaska. Potential breeders were identified as those whose breeding range coincided with the park (as identified by Armstrong, 1990 and Scott, 1987) but were classified as uncommon or rare on the ANHA checklist.

Tetlin: The Refuge checklist of birds (Doyle, no date, and Doyle, 1996) was used as a template for species occurance, and was supplemented by accounts from park staff. While the list lumps confirmed breeders and probable breeders together, information on confirmed breeders was passed on by refuge biologists. Species considered probable breeders by Doyle (1997) were then assessed by relative abundance. Those classified as uncommon or rare were considered potential breeders within the refuge as opposed to probable breeders which was the classification used to assess probable breeders. Those species noted as residents on the Refuge checklist were assigned to the probable breeding category where breeding has yet to be confirmed.

TABLE D2
MAMMALS OF THE ST. ELIAS MOUNTAIN PARKS AND TETLIN NWR

		WRST	KNP	GLBA	TAT	TETLIN
INSECTIVORA						
SORICIDAE						
Sorex cinereus	Masked Shrew	•	•	•	•	•
Sorex vagrans	Vagrant Shrew		•	•		
Sorex obscurus	Dusky Shrew	•	•		•	•
Sorex palustris	American Water Shrew		•	•	•	•
Sorex arcticus	Arctic Shrew					•
Microsorex hoyi	Pigmy Shrew	•	•			•
CHIROPTERA						
VESPERTILIONIDAE						
Myotis lucifugus	Little Brown Bat	•	•	•		•
LAGOMORPHA						
OCHOTONIDAE						
Ochotona collaris	Collared Pika	•	•		•	•
LEPORIDAE						
Lepus americanus	Snowshoe Hare	•	•	•	•	•
RODENTIA						
SCIURIDAE						
Eutamias minimus	Least Chipmunk		•		•	
Marmota monax	Woodchuck		•			•
Marmota broweri	Alaskan Marmot					•
Marmota caligata	Hoary Marmot	•	•	•	•	•
Spermophilus parryii	Arctic Ground Squirrel	•	•		•	•
Tamiasciurus hudsonicus	American Red Squirrel	•	•	•	•	•
Glaucomys sabrinus	Northern Flying Squirrel	•	•	•		•
CASTORIDAE						
Castor canadensis	American Beaver	•	•	•	•	•
MURIDAE						
Peromyscus maniculatus	Deer Mouse		•	•	•	
Clethrionomys rutilus	Northern Red-Backed Mouse	•	•	•	•	•
Lemmus trimucrontaus	Brown Lemming	•	•			•
Lemmus sibiricus	Siberian Lemming		•			•
Synaptomys borealis	Northern Bog Lemming	•	•			•
Phenacomys intermedius	Heather Vole		•			
Dicrostonyx torquatus	Collared Lemming					•
Ondatra zibethicus	Muskrat	•	•		•	•
Microtus miurus	Singing/Insular Vole	•	•			•
Microtus pennsylvanicus	Meadow Vole	•	•			•

Microtus longicaudus	Long-Tailed Vole	•	•	•	•	•
Microtus xanthognathus	Chestnut-Cheeked Vole					•
Microtus oeconomus	Northern/Tundra Vole	•	•	•	•	•
Rattus norvegicus	Norway Rat	•				•
Mus musculus	House Mouse	•				•
Neotoma cinerea	Bushy-Tailed Wood Rat		•		•	
DIPODIDAE						
Zapus hudsonius	Meadow Jumping Mouse	•	•		•	•
ERETHIZONTIDAE						
Erethizon dorsatum	American Porcupine	•	•	•	•	•
CARNIVORA						
CANIDAE						
Canis latrans	Coyote	•	•	•	•	•
Canis lupus	Wolf	•	•	•	•	•
Vulpes vulpes	Red Fox	•	•	•	•	•
URSIDAE						
Ursus americanus	American Black Bear	•	•	•	•	•
Ursus arctos	Grizzly Bear	•	•	•	•	•
MUSTELIDAE						
Martes americana	American Marten	•	•	•	•	•
Mustela erminea	Ermine	•	•	•		•
Mustela frenata	Long-Tailed Weasel		•			
Mustela nivalis	Least Weasel		•	•		•
Mustela vison	American Mink	•	•	•		•
Gulo gulo	Wolverine	•	•	•	•	•
Lontra canadensis	River Otter	•	•	•	•	•
FELIDAE						
Felis concolor	Cougar		•			•
Lynx lynx	Lynx	•	•	•	•	•
ARTIODACTYLA						
CERVIDAE						
Rangifer tarandus	Caribou	•	•			•
Odocoileus hemionus	Mule Deer	•	•	•		•
Alces alces	Moose	•	•	•	•	•
BOVIDAE						
Bison bison	American Bison	•				•
Oreamnos americanus	Mountain Goat	•	•	•	•	•
Ovis dalli	Dall Sheep	•	•		•	•

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Nomenclature

The nomenclature used by Chapman and Feldhamer (1982) was followed here.

Methods

Some sources provided detailed information on habitats, relative abundance, and historical accounts, while others indicated only whether a species was known to occur within a particular area or not. Given this variance in information type, the mammal list was generated by tabulating simple presence or absence (positive identification within the respective park) of a species based on these sources and no attempt to assess abundance or status was made. Marine mammals were not included on the list.

FLORA LIST METADATA
(list incomplete and not included here)

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Methods and Nomenclature

The plant list was generated by tabulating simple presence or absence of a species from the above noted references. However the consulted references used very different nomenclatures and this author's limited expertise in botanical taxonomy made complete integration of the list impossible.

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